AEROSPACE INDUSTRIES ASSOCIATION

July 6, 2015

U.S. Department of Commerce
Bureau of Industry and Security
Regulatory Policy Division
1401 Constitution Ave NW
Room 2099B
Washington, D.C. 20230

U.S. Department of State
Bureau of Political-Military Affairs
Directorate of Defense Trade Controls
2401 E. St, NW
12th Floor, SA-1
Washington, DC 25022

ATTN: Kevin Wolf, Assistant Secretary for Export Administration, U.S. Department of Commerce
Ed Peartree, Director, Office of Defense Trade Controls Policy, U.S. Department of State

SUBJECT: ITAR Amendment – Category XII; RIN 0694-AF75

The Aerospace Industries Association (AIA) and our member companies welcome the opportunity to provide comment on the proposed revised rule for U.S. Munitions List (USML) Category XII (Fire control, range finder, optical and guidance and control equipment) of the International Traffic in Arms Regulations (ITAR) and the corresponding controls on the Commerce Control List (CCL) of the Export Administration Regulations. While our members are encouraged with the continued progress on the Export Control Reform (ECR) initiative, we have several concerns, highlighted below, regarding the Category XII proposed rule and corresponding EAR revisions.

AIA continues to support the Administration's goal of eliminating the confusion and ambiguity that arise from overly restrictive control lists that contain numerous redundancies, leading to an inefficient system with an adverse impact on the U.S. economy and by extension the domestic industrial base. With this goal in mind, it is our concern that the proposed Category XII revisions will negatively impact our member companies' ability to compete in the global marketplace.

The intent of the ECR initiative was not to roll-back controls on ubiquitous technologies that have an inherent dual-use purpose and have been controlled as commercial items for decades. Yet, many items with wide-spread commercial availability in foreign markets will either remain controlled under the ITAR, or in fact move from a lower to higher level of control under these proposed changes. In some instances, the proposed controls do not eliminate ambiguity, relying on design intent to determine jurisdiction or parameters that do not reflect military-specific or most-sensitive capabilities that warrant continued control as munitions items. Furthermore, we encourage the elimination of redundant USML entries across categories, which will greatly improve the efficiency with which items can be classified.

Finally, it is critical to have clear and specific definitions for a number of terms used throughout Category XII, the USML writ large, and the EAR, such as the terms "military" and "commercial." We encourage the Administration to use specific performance parameters, some of which we have included below, to clarify these definitions.

AIA and our member companies thank the Administration for their continued efforts in implementing Export Control Reform, and for considering our comments and proposed revisions.

ITAR Amendment - Category XII

General Comments:

Definition of "Equipment" and its use in Cat XII (and other categories)
We request that the current definition of "equipment" be better defined. Currently, the term "equipment" can be applied to almost any item, including any combination of the listed entries in 120.45 (a)-(g). "Equipment" can be hardware or software, it can be an end-item or not, it can be a system or parts, pieces, components of a system or it can be a separate accessory or attachment to a system. We recommend clarifying the term "Equipment" by amending the ITAR definition to: "Equipment is an end-item used in the production, testing, inspection, or maintenance of an end-item, combination of parts, components, accessories, attachments, firmware, or software." Similar to "accessories" or "attachments," "equipment" is often referring to associated articles that are not parts or components of the system itself; but differs in that the functions and capabilities are similar to items as described in the CCL "B" Group.

We further recommend "equipment" be only enumerated or otherwise described in paragraph XII(e). The term "equipment" is not needed in major system and sub-system paragraphs of Cat XII (as well as in Cat XI or others); however, since the term "equipment" has wide-ranging application, it has the unintended consequence of controlling previously XII(e) parts, pieces, components, accessories and attachment as significant military equipment in paragraphs XII(a)-(c). For example, "equipment" is not needed to be described or controlled in Cat XII(b)(2), "Aiming or target illumination systems or equipment having a laser output wavelength exceeding 710 nm." Only the aiming or target illumination "systems" should be controlled as SME; however, the addition of "or equipment" adds controls beyond the system itself to control the tripod, cleaning kit, adapter cables, and even the transport carry bag. These minor equipment items should have moved from XII(e) to the CCL; but, are now controlled and designated SME on the USML.

SME classification for parts, pieces, and components
We recommend parts, pieces and components only be enumerated or described in XII(e) and the SME designation be removed from the XII(a), (b), (c) & (f) major paragraphs. SME designation should only be placed on individual subparagraphs as appropriate and consistent with SME controls for systems, parts, and components, etc. found in other USML categories. For example, XII(a)(1) enumerates fire control systems, but now also controls formerly XII(e) specially designed parts and components as SME. Helmet

mounted display systems for a combat vehicle are designated SME in XII(a)(9); however, if the helmet mounted display is for an aircraft it is not designated SME in VIII(h)(15).

Similarly, controlling all technical data and defense services related to the defense articles enumerated in this category (XII(f)) as SME has broad ramifications on existing commercial practices. We recommend removing SME control from this category or limiting the application of SME to data and services related to items of greatest military significance.

Order of Review

One purpose of ECR was to create bright lines for unambiguous classification of articles; however, similar/identical technologies continue to be described in multiple entries in addition to being subject to various "catch-all" paragraphs on the USML (e.g. fire control systems). At the same time, an article can also have multiple capabilities which meet the criteria in multiple entries, even in different categories, creating conflict and difficulty in classifying the article. For example, by definition every system with a cooled thermal imager meets the requirements of multiple sections of the document. We therefore first recommend reconciling and eliminating duplicate/overlapping entries where ever possible in the USML; starting with this proposed rule.

For example, Category XV (Spacecraft Systems and Related Articles) and Category XII appear to overlap in several areas. While this does not affect licensing jurisdiction, clarification for where an item is controlled is critical to industry compliance with U.S. export control laws and regulations. In particular, some redundant controls may treat an item as SME. Specific examples include, but may not be limited to:

- Spacecraft payload cable: Category XV(e)(17) or Category XII(a)(7)
- Lasers: Category XV(a)(5) or Cat XII
- Spacecraft Gyroscopes: Category XV(e)(13) or Cat XII(d)(3)
- Developmental Imaging Systems: Category XV(e)(18) or Category XII(c)(21)

Second we recommend adding language to §121.1 USML (b)(1) Order of Review to provide clear guidance for the classification of an article that meets the criteria for multiple USML entries. Should the particular characteristics and functions of an article match more than one entry; it is recommended the entry with the highest level of control (i.e. SME over non-SME or MT over non-MT controlled) be the appropriate classification. Also, to better align with the EAR, it is also recommended that enumerated articles or "otherwise described" articles take precedence over "catch all" paragraphs. Finally, if a defense article still meets the criteria for multiple equally controlled sub-paragraphs, the single predominant subparagraph shall take precedence. While these clarifications were not necessary prior to ECR as each USML category had only one "catch-all" paragraph for all parts, components, etc., they are now essential in order for industry to have a common understanding of the order of review for classifying items.

Finally, an order of precedence/review is necessary for USML categories where conflict/overlap remains between air, land, sea, and space systems and their Cat XI and XII components. Category XI currently defers to Cat XII by clarifying "Electronic equipment and systems not included in Category XII of the U.S. Munitions List," but there are still other instances which need to be reconciled. We recommend XI and XII take precedence over other USML categories with the possible exception of Category XV, as it includes Category XI and XII items that are then "space qualified." We recommend similar language be added as found in XI(a) to, as necessary, provide clear guidance on whether Category XV or Categories XI or XII takes precedence. For the remaining categories we recommend adding "not included in Category XI or XII of the USML" as follows:

> Cat VI(f) Vessel and naval equipment, parts, components, accessories, attachments, associated equipment, and systems not included in Category XI or XII of the USML, as follows:
>
> Cat VII(g) Ground vehicle parts, components, accessories, attachments, associated equipment, and systems, not included in Category XI or XII of the USML, as follows:
>
> Cat VIII(h) Aircraft parts, components, accessories, attachments, associated equipment and systems, not included in Category XI or XII of the USML, as follows:
>
> Cat X(a) Personal protective equipment, not included in Category XI or XII of the USML, as follows:
>
> Cat XX(c) Parts, components, accessories, attachments, and associated equipment, including production, testing, and inspection equipment and tooling, specially designed for any of the articles in paragraphs (a) and (b) of this category and not included in Category XI or XII of the USML, (MT for launcher mechanisms specially designed for rockets, space launch vehicles, or missiles capable of achieving a range greater than or equal to 300 km).

Paragraph (a) Fire control, weapons sights, aiming, and imaging systems and equipment:

(1) Fire control systems: We recommend control of these systems, regardless of end use platform (air, land, or sea), under Cat XII and not designated SME. Fire control systems are proposed to be controlled without caveats or exclusion and their specially designed components, as SME, in Cat XII(a)(1). However; fire control computers, stores management systems, armament control processors, etc. are currently non-SME controlled in USML Cat VI(f)(6), VII(g)(12), VIII(h)(16), and also in the catch-all XX(c). We recommend implementing the order of review proposal we have outlined above, removing the redundancy across USML categories by controlling all fire control systems, etc. under one USML entry.

(9) Helmet mounted display systems: We recommend removing this system from USML Cat VIII(h)(15). Cat XII(a)(9) should control all these devices based on stated performance parameters and not on end use. Therefore we recommend removing these systems from USML Category VIII(h)(15). We also recommend they not be SME controlled as they are not SME controlled in Cat VIII(h)(15).

Paragraph (b) Lasers, and laser systems and equipment:

The proposed controls on lasers and laser systems are overbroad, potentially capturing many commercial – and in some cases systems that have been controlled as EAR99 items. The note to (b)(6) notes that the controls on LIDAR and LADAR systems do not apply to certain civil automotive systems. Yet, there are also systems designed and utilized for civilian aviation and meteorological applications deployed in numerous international civilian airports that would apparently be captured under Category XII.

Controlling all LIDAR and LADAR systems as munitions items will inhibit commercial innovation and undermine the U.S. industrial capability to deliver quality systems for the U.S. military. USML controls on these items should be limited to sensitive technologies and military-specific capabilities. Accordingly, paragraph (b) would benefit from not only expanding the exclusion beyond civil automotive applications to include other civilian systems, but also from providing more clearly defined parameters for those items that remain on the USML:

(b)(1) Laser target designators: We recommend defining, in terms of performance parameters, what constitutes a USML laser target designator.

(b)(3)(ii) Laser output wavelength exceeding 1,000nm would control a large number of commercially available laser rangefinders due to the eye safety improvements and availability of low-cost pulsed diodes.

(b)(7) Synthetic aperture LADAR systems with standoff greater than 100m would limit many potential commercial uses for these cameras.

(b)(8)(i) & (ii) The capabilities defined in (8)(i) (resolution of 0.2m or less from an altitude of 16,500 ft) and incorporating a gimbal-mounted transmitter/beam director is easily achieved with commercially available systems with gimbals. The range/resolution requirements specified in (8)(ii) would similarly control capabilities that could be achieved with commercial off-the-shelf components.

(b)(8)(4) Is the intent to control a full system including the algorithms, or just the LADAR capability? Specifying the capability for a heterodyning system with CNR less than 10 is not useful without range parameters, as CNR is range dependent.

(b)(10) Controls on tunable lasers should include a metric for turnability, as there are many commercial products with this capability.

(b)(13) Laser stacked arrays: We request clarification on the location of the power density to be measured, i.e. measured at the laser aperture or elsewhere?

Paragraph (c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores:

(c)(2) Photon detector, micro bolometer detector, etc.: We request further definition/clarification as to what constitutes an "encapsulated sensor assembly."

(c)(4) Two-Dimensions photon detectors, etc.: We request clarification if "greater than 256 detector elements" refers to the total number of elements or the number of elements in either direction.

(c)(10) Gimbals with two or more axes of active stabilization having a minimum RMS stabilization less than 200 microradians, and specially designed etc.: As currently written, we believe the catch and release criteria of the "specially designed" definition would "release" nearly every gimbal under (b)(3) because they have "the same function, performance capabilities, and the same or 'equivalent' form and fit, as a commodity or software that: (i) is or was in "production" (i.e., not in "development"); and (ii) is not 'enumerated' on the [USML]." To better clarify the reason for control, it is suggested that the phrase "specially designed for articles controlled in this subchapter" be rewritten similar to USML XI(a)(5)(i) "are specially designed to integrate, incorporate, network, or employ defense articles that are controlled in paragraphs or subparagraphs of the categories of §121.1 of this part that do not use the term specially designed" and/or define specific military characteristics that warrant control.

(c)(11) Gimbals with two or more axes of active stabilization having a minimum RMS stabilization less than 100 microradians: This paragraph does not distinguish between commercial gimbals and those use in or with defense articles. We recommend adding "specially designed for defense articles in this chapter" to ensure that widely-available and utilized commercial capabilities are not controlled under the ITAR. The note about the "non-removable camera payload" would impact commercial gimbal systems " where the customer would like to switch between various styles of commercial visible cameras. The interchangeability of the camera payload feature is used by numerous film makers who would like to switch between various types of commercial visible cameras to capture various images. The proposed rule would force these commercial users to buy more than one gimbal because they use more than one camera. The note could be rewritten to limit the tampering of the system that could prevent an impermissible camera such as ultra-violet, infrared or laser payload from being used in the gimbal system.

<u>**Paragraph (d) Guidance, navigation, and control systems and equipment:**</u>

Inertial sensor and systems nomenclature: We recommend that inertial sensor and systems nomenclature reflect designations in the 2010 DoD "Policy for International Transfer and Export Control of Inertial Navigation Systems, Gyroscopes, Accelerometers' Other Systems and Related Technology" and the CCL Category 7; namely, Accelerometers; Gyroscopes; Airborne INS; Land INS; Marine INS; IMU and AHRS. We believe a consistent nomenclature would be extremely helpful to industry and the government in relating one classification to another and driving consistency among various requirements. It is also recommended the government work toward aligning all USML, CCL, DOD policies, MTCR and license proviso nomenclatures.

Note to paragraph (d)(1): We recommend deleting "Note to paragraph (d)(1)" as well as removing and reserving USML Cat IV(h)(1), Cat VI(f)(4) & Cat III(c)(1). This would place controls for the same/similar technology for all guidance, navigation and control systems in XII(d) verses multiple USML categories. Navigation systems were already removed from Cat XI and this proposed rule already removes and reserves USML Cat VIII(e) which is also referenced in the "Note to paragraph (d)(1)."

Note 1 to paragraph (d)(2): We recommend deleting "Note 1 to paragraph (d)(2)." All accelerometers should be controlled in this category. USML fuze accelerometers should be controlled in XII(d)(2) vs. III(d) or IV(h) for same rationale above.

We also recommend adding notes to paragraphs III(d) and IV(h) redirecting to XII(d) for accelerometer fuzes, as follows:

> Cat III(d)(2): Safing, arming and fuzing components (including target detection and localization devices) for the articles in paragraph (a) of this category; and
> Note to paragraph III(d)(2): For weapon fuze accelerometers, see USML Category XII(d);
>
> Cat IV(h)(25): Fuzes specially designed for articles enumerated in paragraph (a) of this category (e.g., proximity, contact, electronic, dispenser proximity, airburst, variable time delay, or multi-option) (MT for those fuzes usable in systems enumerated in paragraph (a)(1) of this category);
>
> Note to paragraph VI(h)(25): For weapon fuze accelerometers, see USML Category XII(d).

Note 3 to paragraph (d)(2): We recommend clarifying that the measurement of 'bias' and 'scale factor' refer to one sigma standard deviation with respect to a fixed calibration over a period of one year.

Product line performance: We recommend a note be added to clarify how performance levels should be applied, i.e. are these performance levels against the product line or against each system? It is our recommendation that performance levels be applied against the product line – or model, where a manufacturer has developed a foreign export variant; otherwise there could be instances in which specific items from a product line would fall under USML CAT XII and other items from that product line would fall under CCL Category 7. This could result in significant confusion and increase per unit cost for US suppliers. We recommend using the certification methodology from the DOD Policy as well.

Performance parameters: We recommend that performance levels for USML Category XII be harmonized, excluding several specific exceptions, with "Policy for International Transfer and Export Control of Inertial Navigation Systems, gyroscopes, Accelerometers' Other Systems and Related Technology." DoD has already established that these levels of performance are of interest for control. Maintaining consistency between the DoD Export Policy and the USML would eliminate potential confusion. We recommend the following performance parameters:

Gyroscope: 0.0005deg/√Hr

> Recommend lowering the gyro Angle Random Walk performance value from 0.00125 deg/√Hr to 0.0005 deg/√Hr to better align the gyro with the accel and INS performance values. Angle Random Walk is clearly defined by the industry by invoking the Allan Variance. Rationale: this performance parameter is unambiguous and its value is more consistent with the levels specified for the accelerometer control.

Accelerometers: 10 µg and 10 ppm

> Using the term uncertainty rather than stability provides better clarity as how to define the terms. Note: Defining "uncertainty" and linking that to "stability" in the CCL is required to avoid confusion.

INS: Airborne INS: 0.28 nmph CEP; at a 1 hour period
Land INS: 0.28 mrad secant (Lat)
Marine INS: 0.2 nm in 8 hour period, CEP

> Providing distinct performance parameters for INS configured for airborne, land and marine applications will be easier to both industry and government to understand what is covered by Category XII. Also recommend inserting a statement that INS performance is without position aiding devices

IMU: Gyroscope and accelerometer parameters or airborne INS value

> Industry has two ways in which to describe an IMU; as the performance of the gyros and accels, which make up the IMU, or as an equivalent INS performance expressed in nmph CEP. With the proposed USML performance values, this would result in a bit of an asymmetry since the gyro performance levels are more consistent with an 0.8 nmph CEP performance. Thus, changing to the proposed gyro performance would provide the proper balance.

Given the performance parameters above, we recommend removing USML paragraph entry XII(d)(1)(iii), eliminating the "or 25 g" performance requirement. Assuming that the objective of Category XII is to control inertial performance of strategic value while letting the lower performance inertial be controlled by the CCL, the 25 g "or" condition will result in lower performing inertial systems remaining under USML jurisdiction. Defining performance levels, such as in the DoD Export Policy, is sufficient to maintain the intent of the control. We also recommend that a note be added to paragraph (d)(2) and (d)(3) to clarify that the ITAR "see-through rule" does not apply when these items are integrated into and included as an integral part of an item subject to the EAR.

(d)(6)(iv) GPS receiving equipment "specially designed" for use with rockets, missiles, SLVs, drones, or UAVs capable of delivering at least a 500 kg payload to a range of at least 300 (km) (MTCR Category 1 systems). GPS receiving systems for air-breathing UAVs do not require similar survivability capabilities as those that might be designed for inclusion on a rocket or missile. GPS systems would not be designed to take into account range/payload capability, as it is irrelevant to the operation of the system. Accordingly, this could be interpreted to capture virtually any GPS system capable of airborne operation. Moreover, the control relies on design intent, rather than positive criteria for control. The likely outcome would be that any UAV that integrates a GPS capability would be controlled on the USML, effectively negating previous efforts to control commercial/civilian UAVs on the Commerce Control List.

Paragraph (e): Parts, components, accessories, attachments, and associated equipment:

(9) Infrared lenses, mirrors, etc.: We recommend removing and reserving this entry and controlling these lesser items if "specially designed" on the CCL. Otherwise, we recommend providing performance threshold control parameters for each.

(10) & (11) Signal or image processing electronics: We recommend these items be placed under XI(b), or remove and reserve XI(b), or define/reconcile what is controlled between these USML entries.

(11)(i) Automatic or aided detection etc.: We recommend these terms be defined, including the threshold for what constitutes a "military or intelligence" item. Does the recognition/classification of a generic "man", "truck" or "plane" which can be performed by commercial systems meet this entry threshold or does the recognition/classification have to be a "military" soldier, a tank, or Mig-29. Being able to discriminate a commercial tanker truck or other item may not have any "intelligence" value unless combined with location or the number of trucks over a period of time.

Note to paragraph (e)(11)(ii). As currently written, this paragraph confirms that combining data from two Category XI systems does not constitute sensor fusion and is not USML controlled. This should be clearly stated in the note to ensure that the definition for multi-sensor fusion aligns with other USG standards, such as DoDI S-5230.28.

Paragraph (f): Technical data and defense services:

Notes 1, 2, & 3 to paragraph (f): We recommend the USG confirm their intent not to control any technical data or software which is not enumerated in these notes. As stated in the Supplementary Information of this proposed rule, these notes are revised to clearly describe the technical data and defense services controlled in paragraph (f). Note 2, paragraph A enumerated what software and technical data is "included" in paragraph (f). It did not make any reference or enumerate any entries in paragraph (d); therefore as written, any technical data, including manufacturing know-how, of a USML accelerometer, gyroscope, or INS is no longer enumerated on the USML. If it is the intent of the government to still control this data on the USML, we recommend a complete review of Notes 1, 2 & 3 to paragraph (f).

Note 2 paragraph C: These items are also enumerated or described in USML Cat IX(b). We recommend removing paragraph C or make a reference note in Cat IX(b) that these items are controlled in Cat XII(f).

Defense Services: We were pleased to see the 3 June 2015 published rule clearly state the maintenance of an item subject to the EAR that has been integrated or installed into a defense article not be defined as a defense service.

Software: We agree with the DOS decision to separate "software" from the definition of "technical data." We believe this is a positive step toward a single list and will make it easier to enumerate what software should be controlled as was attempted in Note 2 to paragraph (f).

Administrative Notes

Title: We recommend adding a clarifying comma to the title; "Fire Control, Range Finder, Optical, and Guidance and Control Equipment"

Proper use of "or": The second to last entries in XII(a), XII(b), and XII(c) should have "; or" at the end as done in XII(d) or XII(e) and rest of the USML. The third to the last entry in XII(c) is followed by "or" which should be deleted.

RIN 0694-AF75: Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, etc.

Under the proposed revisions to the EAR, it appears that certain cameras typically used for cinematic or news gathering applications would be moved from the non-ECR (e.g. non-500 or 600 series) ECCNs (e.g. 6A004, EAR99) into more-restrictive ECCNs (e.g. 6A615), increasing the level of control for articles that are in broad commercial use and have foreign availability. This runs contrary to the state purpose of ECR and AIA encourages the Administration to reconsider the implementation of this more-restrictive control.

Best Regards,

Remy Nathan
Vice President – International Affairs
Aerospace Industries Association

From:	Bob McCurrach
To:	DDTCPublicComments
Subject:	ITAR Amendment-Category XII.
Date:	Monday, July 06, 2015 4:07:45 PM
Attachments:	image001.png image002.png

Office of Defense Trade Controls Policy Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII
To Whom It May Concern:

On behalf of AIA, the global trade group representing the vision and imaging industry, we appreciate the opportunity to comment on the proposed changes to the USML.

AIA has reviewed the comments submitted by SPIE, the international society for optics and photonics, and would like to add our support to the positions stated in those comments. AIA serves more than 330 member companies from 32 countries. Corporate AIA members include manufacturers of vision components and systems, system integrators, distributors, OEMs, end users, consulting firms, academic institutions and research groups directly involved with vision and imaging.

Best regards,

Bob McCurrach | Director of Standards Development

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Robotic Industries Association
AIA – Advancing Vision + Imaging
Motion Control Association

Request for Comments: Amendment to the International Traffic In Arms Regulations, Revision of the U.S. Munition List Category XII

Public Notice 9110

RIN-1400-AD32

To the Attention of Regulatory Change, USML Cat XII,
Email to DDTCpubliccomments@state.gov

Airbus Group N.V. offers the following comments in response to Public Notice 9110 pertaining to USML Category XII.

Cat XII b) (8) (v)

The text of the proposed rules reads: "*LIDAR, LADAR, or other laser range-gated systems or equipment, as follows: (v) Systems or equipment that automatically classify or identify….unexploded ordnance or improvised explosive devices (IED)*"

We are concerned that this definition may capture under the ITAR systems which are designed for homeland security (such as unattended baggage screening) and which, having the capability to determine chemical composition also have the capability to identify explosives, and are currently controlled under the EAR.

We suggest adding "specially designed" language in order to authorize the release from the ITAR under 120.41 as appropriate:

Proposed language: *Cat XII b) (v)* ***Specially Designed*** *Systems or equipment that automatically classify or identify ….unexploded ordnance or improvised explosive devices (IED)*

Cat XII b) (13)

The text of the proposed rules reads: "*Binoculars, …googles, or head or helmet-mounted imaging systems or equipment….that incorporate or are specially designed to incorporate any of the following, and specially designed electronics, optics and displays therefor:*"

We are concerned that the "*and specially designed electronics, optics and displays therefor:*" may capture items otherwise controlled under the EAR (such as cockpit displays or light indicators) , which have been modified to be compatible with Night Vision, such as choice of colour or optical filters avoiding blinding pilots wearing night vision googles). These modifications does not bring in themselves any of the capabilities described in the paragraph. We believe that the intent is to capture only items which contribute to the described capability and not items which are merely compatible with the capability.

We suggest completing Note to paragraph (c) 13 as follows:

Proposed language:

Note to Paragraph (c) 13: The articles controlled in this paragraph include ……….and electronics separately. ***This paragraph does not control articles which are not enumerated on the U.S. Munitions List and have been specially designed to be compatible with the articles controlled in this paragraph.***

Cat XII d) (9)

This category captures *"developmental guidance, navigation, or control devices, systems,…"*

We believe that this definition is vague and presents the risk of encompassing any developmental guidance, navigation or control devices, including for commercial aircraft.

Though Note 1 to paragraph (d) (9) states that "This paragraph does not control guidance, navigation or control systems or equipment…..(c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications" ; it is unclear whether a private industry investment would qualify as "other funding authorization"

We suggest that either the language in the description limits to "guidance, navigation, or control devices, systems specially designed for application for Defense Articles" or that the Note clarifies "private or public funding"

Proposed language:

Developmental guidance, navigation or control devices, systems ***for use in or with a Defense Article****, or equipment funded by the Department of Defense…….*

or

Note 1 to paragraph (d) (9): This paragraph does not control guidance , navigation or control, systems ….(c) identified in the relevant Department of Defense control or ***otherwise documented*** *as being developed for both civil or military applications*

For further information, please contact Corinne Kaplan at 703-466-5741 or Corinne.Kaplan@eads-na.com.

Respectfully,

Pierre Cardin

SVP, Group Export Compliance Officer

Alexander Groba

Coordinator U.S. Regulations

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PUBLIC SUBMISSION

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International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0010
Comment on DOS-2015-0027-0001

Submitter Information

Name: Anonymous Anonymous

General Comment

My comment is to look at what ITAR regulations did to the satellite industry. If this change goes through, the same will happen to the telecom industry and the burgeoning industry for self driving cars. Please review this link for a little history.

http://csis.org/files/media/csis/pubs/081023_lewis_satellitetech.pdf

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Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0029
Comment on DOS-2015-0027-0001

Submitter Information

Name: Anonymous Anonymous

General Comment

Comment 1.

Control (c)(12)(viii) which controls IR camera cores should only control cores with IRFPA having 328,000 detector elements.

Modules having more than 111,000 detector elements are readily available in Germany (http://www.aim-ir.com/en/main/products/modules.html).

Comments regarding the proposed rule "Amendment to the ITAR: Revision of USML Category XII"

Subject: RIN1400-AD32

Summary: Since adequate control criteria do not exist and cannot be positively enumerated, as detailed in the text, the revision should be rewritten with "specially designed for military use"as the fundamental criteria.

Category XII-Fire Control, Range Finder, Optical and Guidance and Control Equipment

Comment: Category XII: paragraph (a)(2)(i)- The text does not offer a'bright line' when it uses the word 'any' to describe specific regulations. The requirement that 'any' infrared focal plane array (IRFPA) having a peak wavelength exceeding 1000 nm that can be used as a weapon sight is confusing. It does not distinguish between a 'photon' IRFPA and a 'thermal" IRFPA nor the pixel density. The former requires an 'active' illumination from an external source. The 'thermal' format utilizes the inherent target temperature. This wavelength specification is a catch-all metric encompassing the entire electromagnetic spectrum beyond one micron. There should be an operational spectral range in describing the wavelength similar to Commerce's CCL controls. Recommendation is to use industry standard nomenclature for SWIR, MWIR, LWIR, and VLWIR (see paragraph (c)(12) comments).

Comment: Category XII: paragraph (c)- The description is overly complicated. "Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:". It includes physical items (e.g. "IRFPA"), applications (e.g. "night vision"), operating wavelengths ("infrared and terahertz systems) and a catch-all term "accessories". A clearer explanation without 'mixing' devices, applications, or characteristics would be advised.

Comment: Category XII: paragraph (c)(2)- This description is confusing with terms like photon detector, microbolometer detector, or multispectral detector appended to infrared focal plane arrays (IRFPA). The point is to have a common metric for the general IRFPA. Presently, the wavelength range 900 nm to 30,000 nm and the mechanical sensor assembly are provided as the key description. However, the wavelength range is in conflict with the greater than 1000 nm wavelength range specified in (a)(2)(i). There is a reference to 'detector elements' without any further description. Finally, a new designation 'permanent encapsulated sensor assembly' is presented; however, it has not been identified. This is the first mention of a new IRFPA commodity description. Recommendation is to generate a dedicated note defining this new assembly.

Comment: Category XII: paragraph (c)(3): The one-dimensional linear photon array with up to 640 elements is incompatible with the Commerce Control List 6A002.a.3.d; 6A002.3.d.1; 6A002.a.3.d.2 and its Technical Note. Addendum 1 lists the appropriate CCL paragraph. The number of array elements is not a critical metric nor is the operating wavelength (absent); however, the element geometry is important. The linear array is available in two geometries: square element and rectangular element. The former can be used in 'imaging' applications where one axis is moving (conveyor belt, moving aircraft). The major conveyor belt application is the recycling industry, food processing industry (almond picking), machine vision, etc. Aircraft applications include remote sensing (fire detection, vegetation, forest canopy). The rectangular element linear array's primary application is spectroscopy (e.g., dispersive & Raman) and instrumentation (e.g., Dense Wavelength Division Multiplexing,). Its geometry is suited to 'slit' spectroscopy and it is not used in imaging applications. It's primary industrial use is in food inspection, agriculture monitoring, moisture measurements, semiconductor process monitor, and biomedical, chemical, pollution, & environmental monitoring. Presently, the major global OEM vendors (Hamamatsu (Japan), Xenics (Belgium), & UTC/Sensors Unlimited (USA)) offer 1024 element square and rectangular SWIR linear arrays. Xenics has announced a commercial 2048 element linear array. All the aforementioned linear arrays are 'permanently encapsulated sensor assemblies'. Recommendation is to revise the 'proposed rule' to focus on 'specially designed for military use' as the principal evaluation parameter in determining ITAR precedent.

Addendum 1.

a.3.d. Non-"space-qualified" linear

(1-dimensional) "focal plane arrays" having all of the following:

a.3.d.1. Individual elements with a peak response in the wavelength range exceeding 1,200 nm but not exceeding 3,000 nm; *and*

a.3.d.2. Any of the following:

a.3.d.2.a. A ratio of 'scan direction' dimension of the detector element to the 'cross-scan direction' dimension of the detector element of less than 3.8; *or*

a.3.d.2.b. Signal processing in the detector elements;

Note: *6A002.a.3.d does not control "focal plane arrays" (not to exceed 32 elements) having detector elements limited solely to germanium material.*

Technical Note: *For the purposes of 6A002.a.3.d, 'cross-scan direction' is defined as the axis parallel to the linear array of detector elements and the 'scan direction' is defined as the axis perpendicular to the linear array of detector elements.*

Comment: Category XII: paragraph (c)(4)- The 'proposed' rule is an egregious misunderstanding to the 2-dimensional (2D) photon based IRFPA development. The recommendation to control area arrays with greater than 256 elements is inconsistent with the technology. This would limit the maximum size of a 2D IRFPA that is not controlled to a 16x16 sensor. There are no commercial products with this type of device. The pixel density is not an indicator to the 'quality' of an IRFPA. Presently, 2D photon IRFPA operating in the SWIR, MWIR, and LWIR are available with greater than 1 million pixels (elements). SWIR focal plane arrays are offered by a number of foreign vendors such as Chunghwa Leading Light (Taiwan), Sofradir (France), Semiconductor Devices (Israel), Hamamatsu (Japan) with pixel density exceeding the proposed 256 elements. All devices are packaged as 'permanent encapsulated sensor assembly'. The manufacturers do not offer 'bare' elements (ROIC or FPA) for commercial sale. Recommendation is to revise the proposed rule for the 2-dimensional (2D) photon based IRFPA described in (c)(4) to eliminate the pixel density, and concentrate on defining 'specially designed for military use' as the key metric. The requirement for a 'permanent encapsulated sensor assembly' allows this item to fall under the CCL aegis.

Comment: Category XII: paragraph (c)(5)- The proposed rule concentrates on a single performance metric (pixel density) without explaining its importance. The 328 000 pixel array limit captures thermal based IRFPA with up to 640x512 sensor (327 680 elements); however, it places USA manufacturers at a disadvantage. Global supplies such as Jenoptik (Germany), ULIS (France) and SCD (Israel) offer 1024x768 (786 432 pixels) offer a 'permanent encapsulated sensor assembly' for global commercial sales.
Recommendation is to remove the pixel density limit, and to specify 'specially designed for military use' for ITAR control.

Comment: Category XII: paragraph (c)(9)(i)- The subset discusses cryocoolers having a cooling source temperature below 218 K. This temperature is equivalent to -55.15 ºC. The National Institute of Standards and Technology has chosen to consider the field of cryogenics as that involving temperatures below −180 °C or −292.00 °F or 93.15 K. This is a logical dividing line, since the normal boiling points of the so-called permanent gases (such as helium, hydrogen, neon, nitrogen, oxygen, and normal air) lie below −180 °C (93.15 K). A cryocooler is a stand-alone vessel that is used to cool some specific application to cryogenic temperatures. It is wrong to classify cooling vessels using the thermoelectric effect as a cryogenic material. This would put unintended controls on any IRFPA mounted in a thermoelectrically cooled module. The 'integrated dewar cooler assembly' (IDCA) is usually classified as a closed-cycle vessel known as a 'Stirling engine' to reach cryogenic temperatures.
Recommendation is to change the text in paragraph (c)(9)(i) from the 218 K source temperature to 93.15 K. This subsection does not clearly explain the rationale for controlling IDCAs at non-cryogenic temperatures.

Comment: Category XII, paragraph (c)(12)- The paragraph is too confusing with its attempt to capture all aspects of infrared imaging within the following topics: image intensifier tubes (catch-all subset without any clear lines between commercial and military (dual-use) applications), IRFPA 'camera cores' covering the SWIR, MWIR, LWIR, and VLWIR electromagnetic spectrum (requires standard nomenclature when discussing spectral wavelengths with respect to photon detection and thermal detection). Presently, (c)(12) uses wavelength bands not associated with the CCL wavelengths. Recommend using the following wavelength definitions:

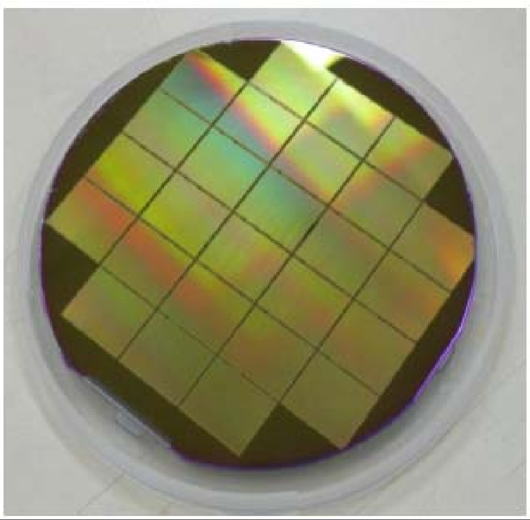
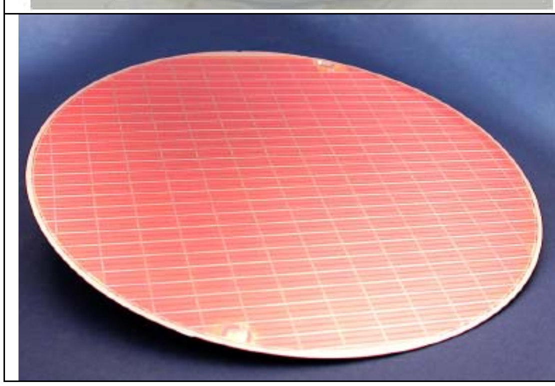
- Near-infrared: from 0.7 to 1.0 µm (from the approximate end of the response of the human eye to that of silicon).
- Short-wave infrared: 1.0 to 3 µm (from the cut-off of silicon to that of the MWIR atmospheric window). InGaAs covers to about 2.5 µm; the less sensitive PbS photoconductor also cover this region.
- Mid-wave infrared: 3 to 5 µm (defined by the atmospheric window and covered by InSb and HgCdTe and PbSe).
- Long-wave infrared: 8 to 12 µm or 7 to 14 µm (this is the atmospheric window covered by HgCdTe and microbolometers).
- Very-long wave infrared (VLWIR) (12 to about 30 µm, covered by HgCdTe and doped silicon),

Additionally, this section has mixed units confusing photon and thermal imaging, variable pixel density dependent on photon linear array, photon area array, and thermal area array. Confusing references are made to earlier paragraphs mixing dual-use terminology. Pixel density is no more a critical metric in linear/area arrays as is the wavelength band or geometry (square/rectangular/circular). The inclusion of an "integrated dewar cooler assembly' (IDCA) within this category is confusing. There should be a separate paragraph especially since it's unknown the specific operating wavelength band, and IRFPA requirements (photon or thermal excitation). Paragraph (c)(12) titled 'infrared imaging camera cores' misses the essence of this document 'Amendment to the ITAR: Revision of USML Category XII' to provide the 'bright line' between USML and CCL control.

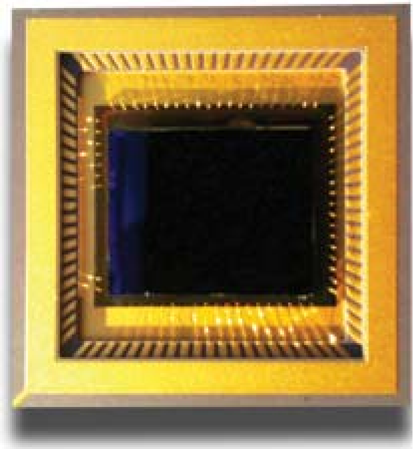
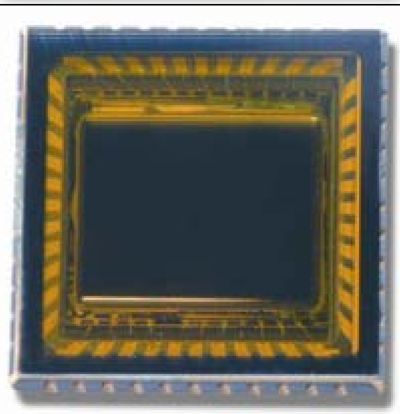
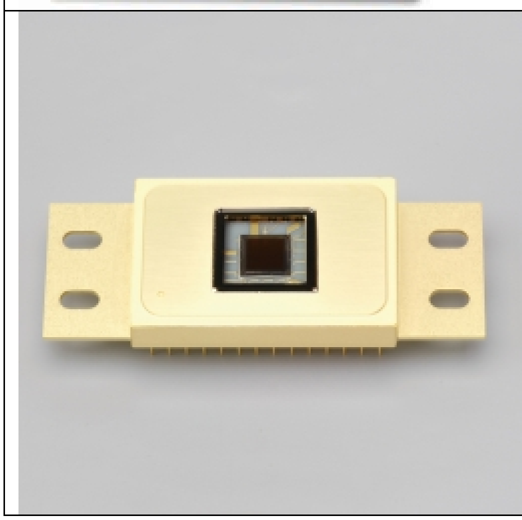
It is further recommended that 'specially designed for military use' be the key metric to classifying an commodity ITAR on the USML.

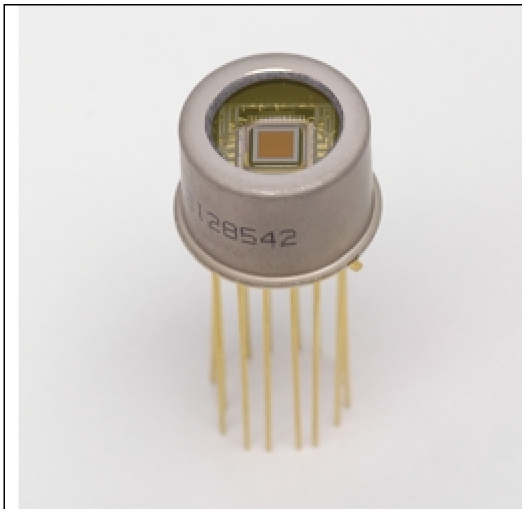
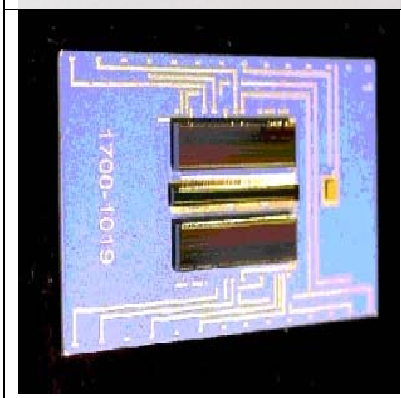
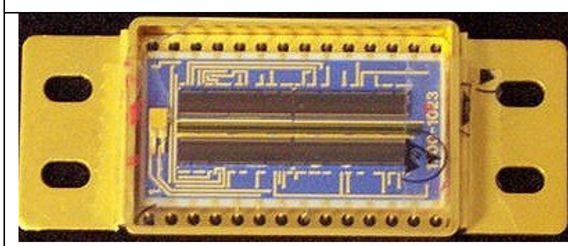
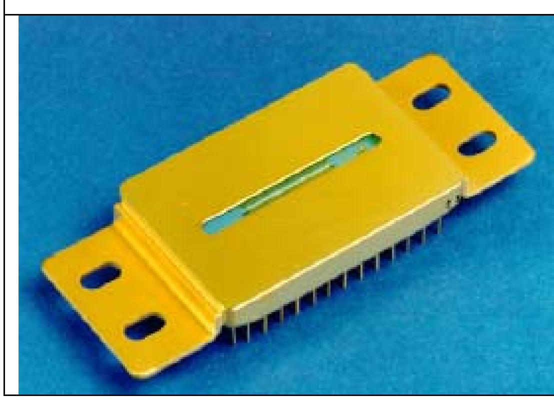
Addendum: Permanent Encapsulated Sensor Assembly

The clarifications of the EAR/USML items that are undergoing “rule changes” are critical to identifying components. This comment discusses the “sensor” for the proposed amendment to ECCN 6A002 and the revision of the Category XII USML describing “encapsulated focal plane arrays” modules. Infrared Focal Plane Arrays (IRFPA) are categorized into two geometries: linear array (1-dimensional) and area array (2-dimensional). These two items are divided into a “stand-alone” photodiode array, a “stand-alone” photodiode array with a “stand-alone” discrete readout integrated circuits (ROIC), and a hybridized photodiode array physically attached via indium solder to a Si ROIC. These “IRFPA components” are integrated into a “permanent encapsulated sensor assembly” module. Several examples illustrating the area (imaging) array and linear (spectroscopy) array are attached. The end-user is unable to change the photodiode array or readout integrated circuit without damaging the IRFPA module. This sensor assembly should be classified within the Commerce department’s CCL. It would not be within the USML guidelines (unless specially designed). An IRFPA that is not permanently encapsulated would be classified under ITAR control. The first graphic illustrates the photodiode array wafer processed into individual die, and a photograph showing the readout integrated circuit wafer (ROIC). The user could select an optimized photodiode array and to an optimized ROIC; thereby side stepping the proposed rule. These would fall under the USML ITAR designation.

	A 100 mm diameter InP wafer with 26 sensors diced into a 1280 x 1024 InGaAs/InP area photodiode array (PDA). The bare die can be hybridized to any suitable ROIC. This provides the condition for ITAR control.
	A 152 mm diameter Si wafer with readout integrated circuits (ROIC). This Si wafer is diced into ROIC chips. The bare die can be hybridized to any compatible two-dimensional photodiode array. These items fall into ITAR control.

The subsequent graphics illustrate the "permanent encapsulated sensor assembly" for the linear and area focal plane array.

	Xenics (Belgium) XFPA-1.7-640: InGaAs SWIR photodiode array hybridized to Si ROIC and permanently encased to a leadless chip carrier (LCC). The user does not have individual access to either the photodiode array or ROIC.
	Chunghwa Leading Photonics (Taiwan) graphic illustrating its two-dimensional InGaAs SWIR photodiode array hybridized to a Si ROIC. This IRFPA is classified as a 'permanently encapsulated sensor' in an LCC module.
	The Hamamatsu (Japan) model G11097-0707S is a two-dimensional InGaAs SWIR photodiode array hybridized to a Si ROIC. The IRFPA is hermetically sealed in a metal dual inline package (DIP) illustrating the "permanent encapsulated sensor assembly" format. The user does not have direct access to the IRFPA without destroying it.

	The Hamamatsu (Japan) model G12242-0707W is a two-dimensional InGaAs SWIR photodiode array hybridized to a Si ROIC. The IRFPA is hermetically sealed in a TO-8 package. This illustrates the 'permanent encapsulation sensor assembly' construction. The user does not have access to the IRFPA without destroying the item.
	The Sensors Unlimited (USA) Linear photodiode array (PDA) (center) and two ROICs bonded onto a ceramic carrier. This is an example of the stand-alone PDA and stand-alone ROIC. These elements are permanently bonded to the ceramic substrate. Neither the photodiode array (PDA) nor the ROIC can be removed.
	The Sensors Unlimited (USA) Linear photodiode array (IRFPA) submount attached to 14-pin dual inline package (DIP). The IRFPA is fixed within the DIP. The user has no ability to individually change elements without permanent destruction.
	The Sensors Unlimited (USA) 'permanently encapsulated sensor assembly' employing an InGaAs IRFPA assembly. The internal components can't be accessed without catastrophic damage to the IRFPA.

Addendum: 9 Hertz Uncooled Thermal Imaging Camera (UTIC)

. This revision would force the regulation of the 6A993 microbolometer based thermal imaging camera (currently classified as EAR99) back into the aegis of the CCL control. The BIS spent considerable time and effort working with the original equipment manufacturers (OEM) that a reduced frame rate based thermal camera could be separated from the 30 Hz and higher frame rate cameras governed by ECCN 6A003. Through diligent effort the "9 Hertz" uncooled thermal imaging camera was successfully developed, and it was given a 6A993 classification. The global OEM vendors have spent considerable effort to market this low frame rate thermal imaging camera for commercial applications such as fire detection, non-contact thermometry, predictive maintenance, building inspection, advance driver assistance systems, etc. The 6A993 designation immediately 'leveled' the 'playing' field with respect to the international market. The USA manufacturers were no longer at a disadvantage in the international market. It is a disservice to reclassify the "9 Hertz" thermal imager because it might be used in a military application.

Unknown at the time of the original classification was a 'future' application to take this 6A993 commodity into the "consumer" world. Recently, uncooled thermal imaging cameras (based on ECCN 6A003.b.4.b) have been developed as an accessory to the "Smartphone". This is a major event in the 'photonics' industry whereby the thermal infrared operating in the 7 to 12 micron spectrum is accessible to the global 'consumer' market. Global vendors FLIR (USA), Seek Thermal (USA), i3systems (Korea), and Opgal's Therm App (Israel) are currently or are in the process of selling these 9 Hertz thermal imaging cameras that are directly connected to a Smartphone. These 9 Hertz cameras are sold directly through vendors such as Amazon, Best Buy, Home Depot, Walmart, etc. as well as their own websites without any reference to CCL/ITAR. Each of the aforementioned products operate with a 9 Hertz or lower frame rate. They require no formal expertise to operate the camera. Software applications have been developed and are openly available from the Apple and Google platforms to operate the thermal camera with Apple or Android equipped Smartphones. It is a disservice to American industry to place restrictions on this novel consumer product. Additional foreign manufacturers will join this fast growing and global market using the microbolometer based IRFPA manufactured from non-USA sources. It is impossible to know the end-use or end-user when purchasing an accessory for the ubiquitous Smartphone. Consequently, it is unrealistic to attempt to control the 9 Hertz thermal camera because it might be used for a military application.

Attachments:

1. FLIR-ONE-GEN2_Android-iOS (USA)
2. Therm-App by Opgal- Sales Brochure (Israel)
3. i3 Systems-Prototype Uncooled Thermal Imaging Camera for Smartphone (Korea)
4. Seek Thermal-Uncooled Thermal Imaging Camera for iPhone and Android (USA)

FLIR ONE F.A.Q.

What is the FLIR ONE?

Available in two new second generation models mid year, FLIR ONE is a thermal camera that attaches to Android or iOS devices that visualize the otherwise hidden world of heat. Equipped with an enhanced Lepton thermal camera core, the FLIR ONE combines visible and thermal images together using a patented technology called MSX to make the thermal image crisper and more recognizable. Everything around us is either emitting or reflecting thermal energy and with the ability to see it and measure it on a mobile device, we can interact with and understand it in useful, interesting and fun ways. FLIR ONE extends human vision. It is the new sixth sense.

How are the new FLIR ONEs better than the original?

Available in either iOS or Android hardware versions, FLIR ONE features:

- A more powerful thermal sensor with four times the resolution for crisper and clearer thermal images.
- Automatic tuning. There is no need to manually tune the device for optimum use.
- A lighter-weight design that is less than a third the weight of the original.

The device retains its own dedicated battery and has the side-by-side visible and thermal cameras. When combined through MSX, the software dramatically increase a user's ability to interpret a thermal image in real-world environments.

How should I refer to the new FLIR ONE?

Two new second-generation FLIR ONE models will be available. One compatible with Android phones that use the Micro USB interface, and one for Apple iOS devices that use the Lightning connector. These products will be known as ***FLIR ONE for Android*** and ***FLIR ONE for iOS***, respectively. Refer top the original FLIR ONE as the first generation FLIR ONE.

What is the price point of FLIR ONE?
FLIR ONE is available worldwide for MSRP $249.99 U.S.

What is the launch date of the next-generation FLIR ONE? When will it ship?
As of June 25, 2015, the FLIR ONE is available for purchase worldwide through FLIR.com/FLIRONE.

How can I purchase FLIR ONE?
In addition to purchasing through FLIR.com/FLIRONE, availability at Amazon, Apple.com and BestBuy.com is expected in July followed by worldwide a roll out in major retailers during the calendar-year third quarter, including The Home Depot and Best Buy.

I'm a dealer/store owner and would like to sell FLIR ONE. Who do I contact?
If you are interested in becoming a channel partner for FLIR ONE, please contact Keith Geck at Keith.Geck@FLIR.com.

Which mobile devices are compatible for use with this generation of FLIR ONE?
The latest generation of FLIR ONE is compatible with Android products with a micro-USB and Apple products with a lightning connector, including the Nexus 6, Samsung Galaxy S6, iPhone 6, 6 plus and iPad, among other devices.

With this new version, how long will you offer the FLIR ONE case for iPhone 5/5s?
The FLIR ONE case will continue to be offered for sale through FLIR.com. We will provide guidance on how long we will continue to sell the first generation FLIR ONE at a later date.

What is FLIR doing to encourage app development?
The FLIR ONE Developer Program is an entire campaign dedicated to enabling developers to create innovative and useful apps for the FLIR ONE. Developers are encouraged to join the program to gain access to FLIR ONE development tools, resources and training to become a FLIR Certified Developer. The new FLIR Approved Applications program gives developers access to additional resources and tools to make their apps as compelling as possible and gives consumers some assurance that apps bearing the FLIR Approved Applications badge have been reviewed by FLIR and deliver thermal imaging benefits to consumers.

Where can I get the FLIR ONE SDK?
An updated FLIR ONE SDK for the iOS platform is available at http://www.flir.com/flirone/developer, which is compatible with the original FLIR ONE and the new FLIR ONE for iOS. A new SDK for FLIR ONE for Android is in beta now and will be publicly available in July. With the FLIR ONE SDKs, developers have access to absolute temperature data for all pixels and control the Lepton camera's shutter mode, in both manual and automatic settings.

For information on this program, contact Cal Loo at cal.loo@flir.com.

What other benefits does FLIR provide the developer community?
The FLIR Certified Developer program offers interested developers specific training in thermal imaging technology and the use of the FLIR ONE developer tools, as well as additional technical and business support to bring apps to market. Once certified, the developers can market themselves as FLIR Certified Developers using the FLIR Certified Developer badge (below). The developer may also be included in the FLIR Developer Universe featured on the FLIR developer website in addition to being eligible for app development business leads from FLIR.

The FLIR Approved Applications program offers developers access to additional resources and tools to make their respective apps as compelling as possible. It also provides consumers assurance that apps bearing the FLIR Approved Application badge have been reviewed by FLIR for quality and value.

Those apps that qualify may be marketed using the FLIR Approved Application badge (below) and may be included in the FLIR ONE applications gallery on the FLIR developer website and included in the "Feature App" listing. Additional benefits include the possible complementary promotion on FLIR.com and FLIR-owned social media channels.

While FLIR can't assume responsibility for the apps developed by any independent developers, this program offers consumers assurances that apps bearing the FLIR Approved Applications badge are of good quality and offer thermal imaging value to customers.

FLIR APPROVED APPLICATION

FLIR CERTIFIED DEVELOPER

What is FLIR doing to recruit developers to the FLIR Developer Program?
FLIR recently launched the "Bring the Heat" event campaign, which is a series of hacker and maker challenge events set around the world. At these events, software developers come together in the spirit of collaboration and competition to brainstorm thermal imaging-related ideas and to evolve them into real applications for cash and product prizes. FLIR provides the venue, the hardware and software tools along with mentoring and technical support. Developers provide the smarts, the ingenuity and passion to create great apps.

For more information, check out the events page at http://www.flir.com/flirone/developer.

What if I can't physically attend and participate one of the "Bring the Heat" hacker challenge events?
We want to include and encourage developers all over the world to bring their creative ideas and skills to FLIR ONE. In the near future is launching a global, online Bring the Heat hacker challenge. Developers will be able to register on ChallengePost, develop and test their apps using either a physical FLIR ONE device or an online simulator, and submit their respective apps online to compete for cash and product prizes.

Stay tuned for more information at http://www.flir.com/flirone/developer.

What apps will be available for use with FLIR ONE?
The primary FLIR ONE app has been updated with the introduction of the new FLIR ONE models and is available for free download on the Apple App Store and the Google Play Store. Additionally, FLIR is working with multiple flagship developers through the FLIR Developer Program to create apps that address specific user groups with features and capabilities that suit a variety of needs.

Some examples of the many new apps that are or will soon be available, include:

- **Comfort Tracker:** guides homeowners and professional contractors through a home energy assessment to identify opportunities to improve comfort and efficiency by recommending solutions and identifying local retailers of Owens Corning insulation.
- **Manything:** a free app that turns spare iOS devices into video monitoring cameras and has integrated the FLIR ONE to enable remote thermal vision, temperature triggered alerts and thermal motion detection, even in total darkness.
- **Zombie Vision:** turns your FLIR One enabled mobile device into a fun, real-time Zombie locator.
- **Everfave:** Innovative iOS and Android app for consumers to discover and share recommended businesses and pros. Consumers earn rewards for sharing their experiences and recommendations with their friends.
- **Infrahorse:** aides horse enthusiasts in determining 'hotspots' or asymmetry in a horse's legs, hooves or back that may denote a potential health issue.

What would I use FLIR ONE for?
Thermal imaging makes the otherwise invisible world of heat energy visible to your eyes. Everything around you either emits or reflects heat energy. For example, with FLIR ONE, when you look around a room in your home, you can see where doors and windows are not well insulated. You might see a wall switch is slightly warm that could indicate a pending problem or overloaded circuit. The list of uses is long and will grow dramatically as customers discover this unseen portion of the electromagnetic spectrum. Visit FLIR.com/FLIR ONE for educational information on how thermal imaging can and will be useful in everyday life, and discover this previously invisible world first-hand.

I'm concerned about privacy. Can someone use FLIR ONE to spy inside my home or underneath clothes?
FLIR ONE does not provide x-ray vision. It allows you to visualize and measure the surface temperate of most objects. In many cases, the surface temperature of an object can be affected by things behind or under the surface. For example, under certain conditions the surface temperature of a wall can be subtly affected by the wooden studs behind it. This characteristic can allow you to easily see the location of the studs behind the wall, without actually looking through the wall.

Aren't you concerned FLIR ONEs can be used to steal personal information? Like an ATM pin code?
With any new technology in the hands of consumers, there is a chance it will be used in unintended ways. At FLIR, our heritage is to provide the world's most advanced thermal imaging technology for public safety, environmental protection and to enhance our daily lives. Therefore, we take personal security very seriously.
The purported ability to steal pin codes with thermal imaging cameras, such as at ATMs, requires very specific conditions and circumstances making such a scenario highly unlikely. Regardless, we recommend practicing prudent identity protection measures to ensure personal data remains secure no matter the situation.

What is the indoor/outdoor range of FLIR ONE?
At about 100 feet, you can see the heat signature of a person. However, atmospheric conditions can influence the visible range. Dry, clear weather will provide a greater range than rainy, foggy, or humid conditions as water in the atmosphere can absorb infrared radiation before it reaches the sensor.

What is the resolution of the camera?
Resolution is often synonymous with image quality, but in reality, resolution is one of many factors that determine thermal image quality. The new FLIR ONE's more powerful Lepton thermal camera has been upgraded to generate image quality equal to or better than the original in every respect. When combined with the VGA visible camera, FLIR ONE creates a crisper and clearer 640x480 image than ever before. This is achieved with FLIR's patented two-camera MSX™ Technology, which embosses a visible image onto the thermal image without eliminating any thermal information, greatly enhancing the perceived resolution and detail of the thermal image.

How does MSX blending work?
FLIR developed MSX blending as a proprietary and patented technique to improve image quality. It dramatically increases a user's ability to interpret a thermal image in real-world environments by adding visible edge detail to a thermal image without sacrificing detail. MSX is additive in that no thermal information is lost, greatly enhancing the perceived resolution of the thermal image. However, MSX only works in conditions where visible light is present. In dark conditions, turn on the companion-device flashlight to generate light.

Does the FLIR ONE require frequent manual tuning of the shutter to ensure the best experience?
No. The new FLIR ONE now features automatic tuning and thus will not require the user to periodically reset the thermal sensor.

What is the operating temperature for the FLIR ONE?
FLIR ONE operates at 32°F to 95°F (0°C to 35°C). It also features an enhanced scene temperature range of -4°F to 248°F (-20° to 120°C), a 40°C increase in range from the predecessor device.

Will there be a new FLIR ONE that wraps around my mobile device like the previous version?
Because this generation of FLIR ONE is a small and lightweight attachment to mobile devices through either a micro-USB (Android) or a lightning connector (Apple), it provides the user flexibility to use FLIR ONE with multiple device types.

How is the new FLIR ONE powered? Will it drain my tablet/smartphone battery?
No. The attachment includes an internal battery, ensuring that the FLIR ONE won't drain the respective battery of the attached device.

The FLIR ONE adds some bulk and weight to the mobile device. Will it still fit in a pants pocket?
FLIR ONE weighs just 2.75 ounce (~30 grams), which is less than a third the weight of the predecessor. With its small and lightweight form factor, it adds just 0.7 inches (18 mm) of depth and about 2.8 inches (72 mm) in length when attached to an Android smartphone or the iPhone 6, as examples.

Therm-App
more to see.

ANDROID THERMAL IMAGING DEVICE

Unparalleled combination of excellent performance and affordability in a portable, lightweight device

Why Stay in the Dark?

Therm- App™ improves effectiveness in the field, providing clear images in total darkness — delivering mission critical information which can save lives. The compact and lightweight camera with interchangeable lenses enables users to record and immediately share high-quality thermal images and videos. Connecting to most Android smartphones, it offers superb image quality and low power consumption.

Long range detection

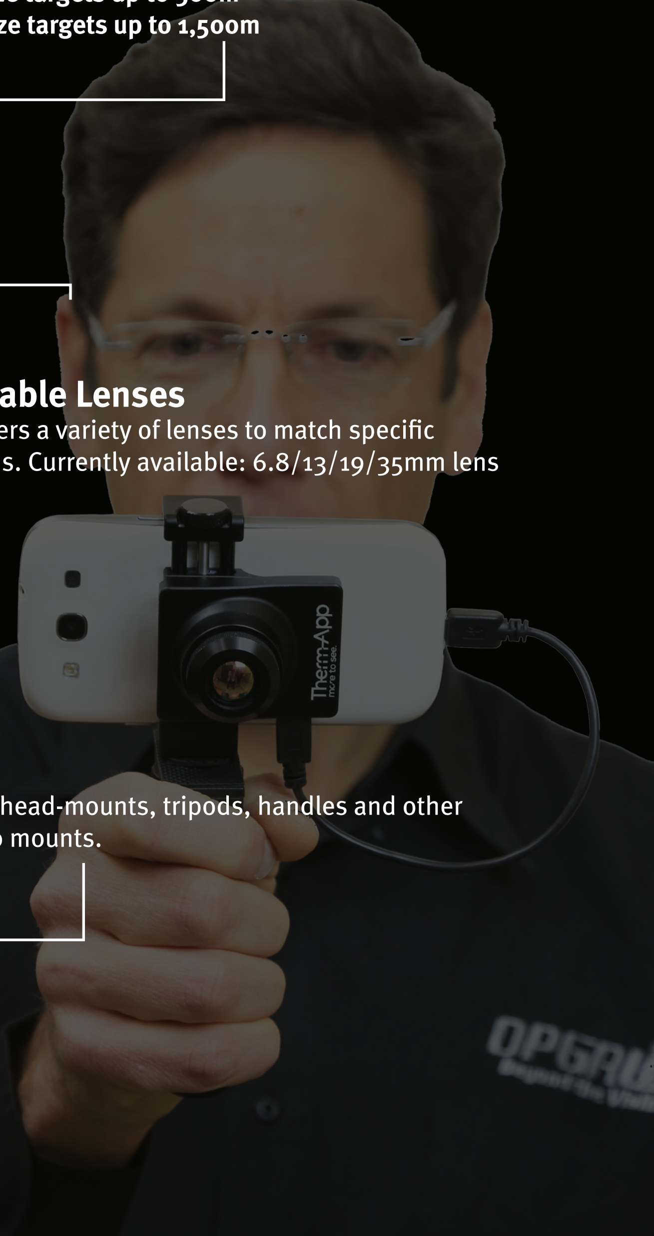
Detect human size targets up to 500m
Detect vehicle size targets up to 1,500m

Interchangeable Lenses

Therm-App™ offers a variety of lenses to match specific operational needs. Currently available: 6.8/13/19/35mm lens options.

Modular

Compatible with head-mounts, tripods, handles and other standard 1/4"-20 mounts.



Improve situational awareness and enhance safety with long-range detection and recognition capabilities.

Security

See the unseen while on routine perimeter patrol, securing a facility, or identifying potential threats in dark or badly lit areas. It's easier to control and secure a perimeter, by obtaining clear images of people, animals, or vehicles at the scene.

Law Enforcement

Improve situational awareness and enhance safety while on patrol, responding to distress calls, exiting patrol vehicles, and entering buildings. Identify perpetrators trying to avoid detection or fleeing the scene.

Wildlife

Obtain a clear view of animals in the wild, irrespective of lighting or weather conditions— through high grass, dense brush, or forested areas.

Search and Rescue

Locate injured or unconscious people on land or in water, in any weather or environmental conditions such as fog or smoke. Detect signs of life even in thick foliage or wooded areas, day or night.

Therm-App™ Technical Specifications

Smartphone	
Minimal Requirements	Android 4.1 and above, supporting USB OTG
Hardware	
Imager	384 x 288 microbolometer LWIR 7.5 -14um
Optics	6.8mm lens (55° x 41°) 13mm lens (29°x 22°) 19mm lens (19°x14°) 35mm lens (11° x 8°)
Focus	Manual, 0.2m to infinity
Frame Rate	8.7Hz
Weight	138 grams / 4.86 ounces
Size	55 x 65 x 40mm (2.16 x 2.55 x 1.57in)
Operating Temperature	-10°C to +50°C (14°F to +122°F)
Storage Temperature	-20°C to +50°C (-4°F to +122°F)
Power Supply	No battery, 5V over USB OTG cable, power consumption < 0.5W
Certifications	CE, FCC, RoHS
Encapsulation	IP54
Mount/Handle	Ergonomic handle, using 1/4"-20 standard tripod mount
Device Attachment	Clip-on for smartphone (5 -10cm span)

Measurement	
Resolution	384 x 288 pixels (>110,000 pixels)
Accuracy	+/- 3°C or 3% (@25°C)
Sensitivity	NETD <0.07°C
Temperature Range Calibration	5 – 90 °C
Software	
Viewing Modes	• Night Vision • Thermography (Basic)
Output	Video & Audio (h.264), Snapshot
Instant Share	Email, SMS
Android Share	Via media gallery
Color Palettes	Hot White / Hot Black / Iron / Rainbow / Grey / Vivid
Zoom	Continuous digital zoom using touchscreen
Software and feature updates	Yes (via Google Play)
Maintenance	Bad pixel repair uilitity

[At night, or in poor visibility conditions, Therm-App™ gives you the full picture.]

TempSensorNEWS

â† 3rd Gen MicroCAM Infrared Thermal Imaging Core

FLIR A6200SC Short Wave Infrared (SWIR) Camera â†’

Prototype Low Cost Smartphone Thermal Imager

Posted on 24/04/2015 by Editor

i3system Shows Hi-Res Device at SPIE-DSS 2015

Thermal Expert Prototype At SPIE.DSS 2015

Baltimore MD, USA â€” i3system showed a prototype high resolution (>110,000 pixels) Smartphone LWIR Thermal Imager named ***â€œThermal Expertâ€.***

It appears intended to compete with the FLIROne and Seek Thermal products already on the market.

i3system already produce LWIR microbolometers in-house with 384X288 @ 25 Âµm pitch having NETD of <50 mK.

Their LWIR engine reportedly draws less than 3 Watts.

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Recent Articles

- FLIRâ€™s new long-range pan/tilt thermal security camera
- National Guard of Virginia relies on photovoltaics monitoring by Lufft
- 2015 DrySyn Classic Heating Block
- Cooled Vs Uncooled Infrared Thermal Imaging Cameras
- Testo at Appetite for

Numbers like $500 per unit with more than 3 times the 32 K pixels of the ~$250 Seek Thermal and were heard resonating on the Expo floor.

i3system Thermal Expert (right) on Smartphone

Could be some more bang for the buck than the lower-priced and lower performance devices already out there. Just check the image on the iPhone to the left!

The next year should see some very interesting developments, to say the least!

i3system is no lightweight in the field of thermal imaging.

They have been developing and selling high-tech imaging sensors in Korea for more than 15 years.

They now also are expanding their commercial business with IR detector and camera electronics for satellite and other applications.

i3system, Inc, founded in 1998, has developed capsule endoscope for medical use and cooled infrared detectors for thermal imaging cameras for Korean military use. We later expanded our business to X-ray imaging detectors for dental X-ray imaging equipments such as panoramic and cephalometric systems. i3system, inc. is officially designated as a military product contractor for Korean military since 2010 by Korean government.We also develop and manufacture uncooled IR detectors for uncooled thermal imaging cameras for commercial products such as security, surveillance, radiometry devices and night vision systems as well as military product for personal rifle of Korean Army. Our products for military use include IR scene projector, real time scene simulator, IR camera and laser detector.

Headquarters/Factory:
69, Techno 5-ro
Yuseong-gu
Daejeon
Korea

Research Center:
26-32, Gajeongbuk-ro
Yuseong-gu

- engineering 2015
- Bangkok tightens measures against spread of Mers
- NEW PyroCube Precision Infrared Temperature Sensor

Meetings, Publications, Standards, Ed & Training

A Fully Nonmetallic Gas Turbine Engine Enabled by Additive Manufacturing, Part II: Additive Manufacturing and Characterization of Polymer Composites
27/06/2015
06/26/2015 "A2LA Today" - June 2015
27/06/2015
A Standards in Trade Workshop on China Brown?elds Remediation
26/06/2015
NIST-led Effort Yields New International Standard for Dynamic Liquid Measuring Systems
26/06/2015
Role of Tropical Atlantic SST Variability as a Modulator of El Nino Teleconnections
26/06/2015
High Throughput Media Preparation at The Institut Curi
26/06/2015
Sensors, Vol. 15, Pages 15067-15089: An Efficient Biometric-Based Algorithm Using Heart Rate Variability for Securing Body Sensor Networks
26/06/2015
EU Environmental Technology Verification (EU-ETV) Workshop
26/06/2015

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Posted in Applications, Display, News, Night Vision, Non-Contact Sensors, Thermal Imaging, Vendors Tagged high resolution-low cost thermal imager for smart phone, i3 system, thermal expert
permalink

â† 3rd Gen MicroCAM Infrared Thermal Imaging Core

FLIR A6200SC Short Wave Infrared (SWIR) Camera â†’

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Post Comment

D3448 Standard Test Method for Specific Aqueous Conductance of Trichlorotrifluoroethane has been editorially changed, available as D3448-10(2015)e1
25/06/2015

D5176 Standard Test Method for Total Chemically Bound Nitrogen in Water by Pyrolysis and Chemiluminescence Detection has been reapproved, available as D5176-08(2015)
25/06/2015

Categories

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Archives

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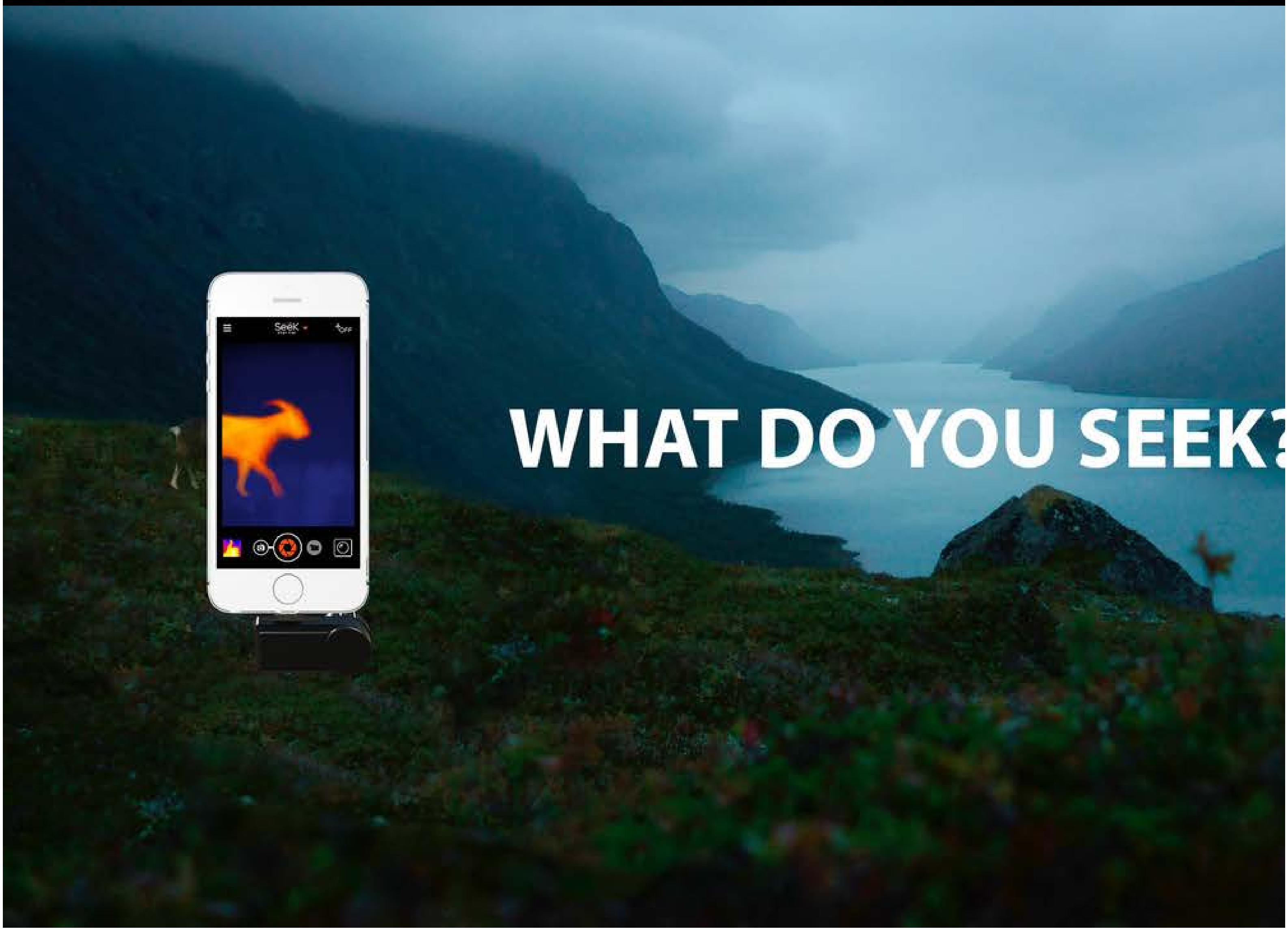
Re: Temps /RH

Global Temperatures | Global Warming, is it Real?
IMPROVING HUMIDITY MEASUREMENTS IN METEOROLOGY
Measuring Moisture in Wood
The Significance of



Seek Thermal Camera

With its wide field of view, the original Seek Thermal camera is perfect for use indoors and around the house.

This camera allows:

- **Contractors** to see water damage, air leaks, missing insulation, and other energy inefficiencies

- **Home owners** and DIYers to conduct a home energy audit to help save on their energy bill
- **Plumbers** to detect water leaks and clogs
- **Electricians** to identify electrical shorts, loose wiring, and other safety hazards
- **Pet owners** to locate lost pets at night or in obscured visibility conditions

206 x 156 Thermal Sensor

36° Field of View

-40C to 330C Detection Range

Protective Waterproof Case

BUY FOR IPHONE

BUY FOR ANDROID

Seek Thermal XR - Xtra Range

The Seek XR is an extended-range version of our award-winning thermal camera. With nearly twice the magnification, the Seek XR lets you see objects at greater distances with the same clarity and resolution as the original Seek camera.

206 x 156 Thermal Sensor

20° Field of View

-40C to 330C Detection Range

Protective Waterproof Case

BUY FOR IPHONE

BUY FOR ANDROID

This model is ideal for:

- **Hunters** to track game, scout terrain, and follow bloodtrails
- **Boaters** to detect harmful objects on the water at night
- **Campers** to quickly scan around a campsite for dangerous animals
- **Electrical Engineers** to inspect components, circuit boards and assemblies
- **Anyone** looking for increased home security can detect intruders from nearly 1,800 feet away

---

Camera Specs

Seek Thermal Specs

- 36Âº Field of View
- Fixed Focus
- Resolution: 206 x 156 Array
- -40C to 330C Detection
- < 9Hz
- Long Wave Infrared 7.2 â€“ 13 Microns
- 12 Âµ Pixel Pitch
- Vanadium Oxide Microbolometer
- Chalcogenide Lens

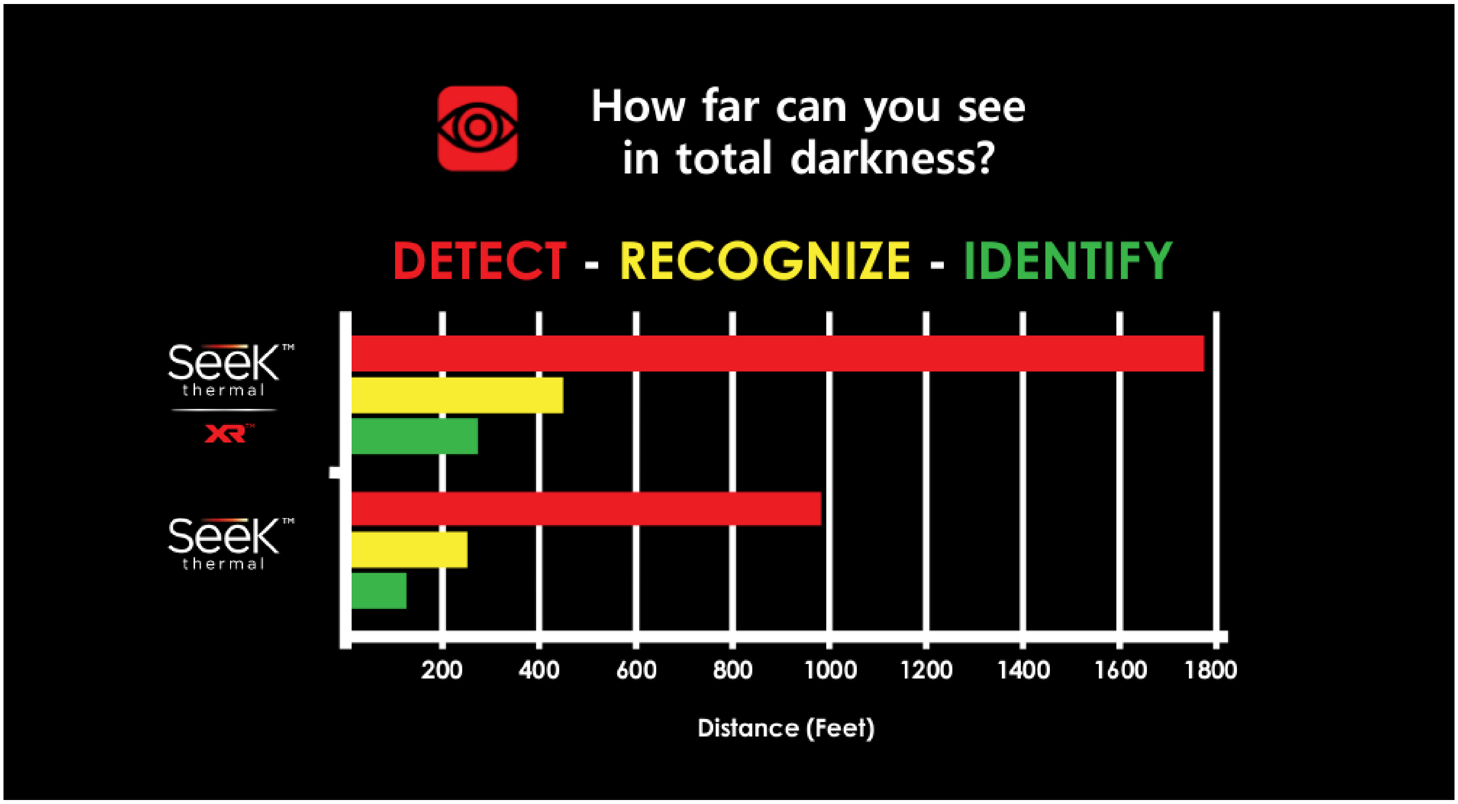
Seek Thermal XR Specs

- 20Âº Field of View
- Adjustable Focus
- Resolution: 206 x 156 Array
- -40C to 330C Detection
- < 9Hz
- Long Wave Infrared 7.2 â€“ 13 Microns
- 12 Âµ Pixel Pitch
- Vanadium Oxide Microbolometer
- Chalcogenide Lens

Magnesium Housing
- Protective Waterproof Case

Magnesium Housing
- Protective Waterproof Case

Check your **phone compatibility** here.



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CONTACT

Anonymous

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Submission Type: Web

PUBLIC SUBMISSION

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International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0017
Comment on DOS-2015-0027-0001

Submitter Information

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Santa Barbara, CA, 93101
Phone: 805-966-3331

General Comment

Response to ITAR Amendment Category XII (b)(13)(i)

See complete comment in the upload, Response to Section (b)(13)(I) of ITAR -7-3-15 Final. Docx, which includes detailed
technical discussions and examples in the appendix.

3 Conclusion
The Section (b)13(i) of the amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List
Category XII would control most of todays commercially used laser stacked arrays and as a consequence any commercial
product using these arrays by the see through rule. The proposed peak pulsed power density limit of 3,300 W/cm2 is
much too low to be able to draw a bright line between military and non-military products and in addition one parameter,
power density, is not adequate to distinguish military products from commercial products. Laser stacked arrays as defined
in (b)(13)(i) are produced and in commercial use around the world and therefore do not provide a critical military or
intelligence advantage to the US. On the contrary, US industry that produces laser stacked arrays or utilizes them in

products like medical or material processing devices for example, would be adversely affected by this limit: They would be
excluded from a growing market and lose market share to, or be put out of business by, international competitors.
4 Proposal for Revised Language:
Proposal 1: delete XII(b)(13)(i) as being inappropriate and too poorly parameterized for ITAR control
Proposal 2: Amend XII(b)(13)(i) to read: laser stacked arrays having an output wavelength not exceeding 1,400nm
and a peak pulsed power density greater than 100,000 W/cm2, if specially designed for military applications

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Attachments

Response to Section (b)13 of ITAR - 7-3-15 final

Response to "ITAR Amendment – Category XII" (b)(13)(i)

1 Introduction

1.1 Commenting Organization: ASC

Advanced Scientific Concepts, Inc. (ASC) was founded in 1987 to develop emerging technologies specifically related to enhanced imaging and imaging applications. The company's current focus is 3D Flash LIDAR™ technologies and cameras. The "framing camera" nature of ASC's cameras and its real-time 3D video output makes them ideal for moving-vehicle solutions such as automotive and aviation collision avoidance and navigation systems. All ASC's cameras operate as eye-safe, time-of-flight laser flash systems. As a sub-component for laser pumping are laser stacked arrays of 808nm wavelength where peak power densities between 6.3 and 14 kW/ cm^2 are used. Taking advantage of the increased power density of laser staked arrays in ASC's lasers is one of the company's primary means of maintaining competitiveness in the market.

1.2 Summary of concern

We are concerned with the entry in Category XII(b)(13)(i): "laser stacked arrays having an output wavelength not exceeding 1,400nm and a peak pulsed power density greater than 3,300 W/cm^2".

This entry is overly restrictive because it puts today's standard laser stacked arrays, used for a wide range of non-military, commercial laser applications, under ITAR control. Laser stacked arrays with peak power densities more than 24,000 W/cm^2 are already commercially available in the USA and overseas. The current commercial diode market is moving towards higher energies in smaller packages at lower cost which also opens new application possibilities. If the US diode fabrication industry, as well as the industries that implements these arrays in a variety of applications – like the applications in Section 2.2, Table 2 for example - is controlled under ITAR, they will be excluded from a growing market. ITAR controls on U.S.-origin components that are widely available from many countries around the world, including those which do not share U.S. foreign policy and national security objectives, cannot be effective in denying foreign access to the technology. Where the technology is in widespread civil use, ITAR controls compound the competitive harm to U.S. manufacturers by creating enormous legal risks for manufacturers and potential customers alike, but with no corresponding national security benefit. Furthermore most businesses require investment to grow but the risks and insecurity posed by ITAR control are understandably anathema to commercial-technology investors. Therefore, as seen in Section 4 below, we propose to remove the (b)13(i) entry altogether or raise the power density limit to 100 kW/cm^2,if the devices are specially designed for military applications.

2 Discussion

2.1 Commercial availability of laser stacked arrays

Section (b)(13)(i) of the amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII would control any diode stack array with an output wavelength not exceeding 1400 nm and a peak pulsed power density exceeding 3.3 kW/ cm^2. The commercially available peak power limit of such diode stacks has grown by more than 500% in just a few years as can be seen in Figure 1. Diode arrays with an output power of 300 – 400 W per bar (many bars can comprise a laser stack array) of 1-3 mm length are todays standard, while development continues with the goal of higher power at lower cost. Power output of 1kW/bar has already been achieved [1]. However, exceeding power of ~500 W per bar reaches physical limits and reduce reliability and lifetime of the product. The growing power trend for this particular type of diode array will probably stop somewhere between 500 and 1000W/bar maximum for commercial products. Higher energies might be expected for special high power applications that are not looking for a high number of shots and long lifetime. These might include military applications. Lifetime then is obviously an important performance parameter. Conversion efficiency from electrical to optical energy is also a important performance parameter especially for military equipment run by batteries. Additionally size or dimensions of the laser staked array are important particulary for efficiently pumping small oscillator crystals. Hence (b)(13)(i) inadequately parameterizes the technology to distinguish military applications from commercial applications. Using "specially designed for military applications" in the controls can compensate for inadequate parameterization.

As shown in Figure 1, laser power density is increasing at an exponential rate in a manner consistent with the growth of the semiconductor industry as described by Moore's Law.

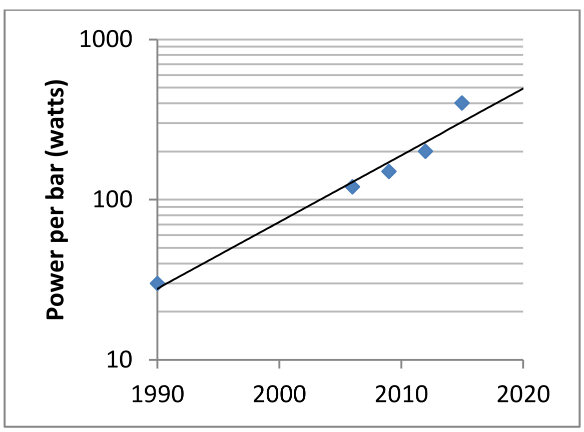


Figure 1: Technology development of laser diodes plotted as the power output per bar since the 1990's and interpolated into the future. Source of values [3].

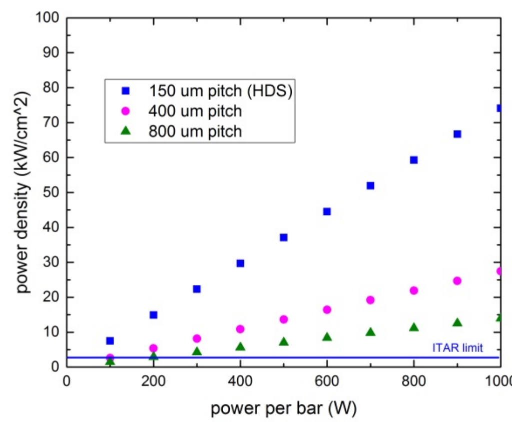


Figure 2: Expected power density of stacked diode arrays depending on package pitch (distance between bars) and power output per bar. It is shown that the proposed ITAR power density limit is at the lower end of the technical standard and would control almost all available stacked products. Values up to 400 W/bar are taken from [2] and then interpolated.

With dense packaging, the peak power density limit of 3.3 kW/ cm^2 is easily exceeded (see Figure 2) as has been demonstrated by Northrop Grumman Cutting Edge Optronics in "Application Note #15" [2]. The proposed peak power limitation would inadvertently control items on the ITAR that are in normal commercial use and are available from vendors around the world including such countries as USA, China, Europe and Japan, to name a few. Specific examples can be seen in Table 1 below. Exemplary data sheets are presented in the appendix, Section 6. To bring the proposed ITAR in line with current commercial offerings and to keep the ITAR from burdening US companies it is recommended that the limit for peak power density of a diode stack be raised to 100 kW/cm^2, if specially designed for military applications.

Country of origin	**Company**	**Peak power density**	**Wavelength**	**Source website**
China	Focuslight	18 kW/cm^2	800-980 nm	http://www.focuslight.com.cn/administrator/img/20141017121282994.pdf
France	Quantel Laser	24 kW/cm^2	790-980 nm	http://www.quantel-laser.com/en/products/item/conduction-cooled-qcw-stacked-array-.html
Germany	Dilas	15 kW/cm^2	980 nm	http://www.dilas.com/pages/products.php?category=16&series=7
Japan	Hamamatsu	5 kW/cm^2	980 nm	http://www.hamamatsu.com/eu/en/product/category/1001/1007/L11398-16P980/index.html#1328440494339
USA	NGC-CEO	25 kW/cm^2	800-980 nm	http://catalog.cuttingedgeoptronics.com/item/high-power-laser-diodes/laser-diodes/arr179p500hds5

Table 1: List of examples of currently available commercial diode stacks.

2.2 Commercial application of laser stacked arrays

Typical commercial applications for such diode stacks include: illumination, hair removal, and solid state laser pumping. An overview can be seen in Table 2. Having laser stacked arrays controlled by ITAR would exclude US diode and laser vendors from international markets in these fields of application.

Diode stack application area	Operating wavelength (nm)
Medical photodynamic therapy	630 - 730
Hair removal, tattoo removal	810
Pre – Press, computer to plate printing	830
Medical	1064
Acne treatment	1450
Turbulence Detection (aviation)	1850
Plastic welding & material processing	1850
Coagulation of Protein (Medical)	1900 - 2000

Table 2. List of commercial application examples for high power laser diodes and arrays (source [4]).

3 Conclusion

The Section (b)13(i) of the amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII would control most of today's commercially used laser stacked arrays and as a consequence any commercial product using these arrays by the "see through" rule. The proposed peak pulsed power density limit of 3,300 W/cm^2 is much too low to be able to draw a bright line between military and non-military products and in addition one parameter, power density, is not adequate to distinguish military products from commercial products. Laser stacked arrays as defined in this section are produced and in commercial use around the world and therefore do not provide a critical military or intelligence advantage to the US. On the contrary, US industry that produces laser stacked arrays or utilizes them in products like medical or material processing devices for example, would be adversely affected by this limit: They would be excluded from a growing market and lose market share to, or be put out of business by, international competitors.

4 Proposal for Revised Language:

Proposal 1: delete XII(b)(13)(i) as being inappropriate and too poorly parameterized for ITAR control

Proposal 2: Amend XII(b)(13)(i) to read: "laser stacked arrays having an output wavelength not exceeding 1,400nm and a peak pulsed power density greater than 100,000 W/cm^2, if specially designed for military applications"

5 References

[1] P. Crump. Et al., "Progress in high-energy-class diode laser pump sources", Photonics West 2015, SPIE 9348-30, http://www.dilas.com/pages/library.php?mode=technicalpapers

[2] Northrop Grumman Cutting Edge Optronics, "Application Note #15 – High density pulsed laser diode arrays for SSL pumping", March 29th 2010, http://www.northropgrumman.com/BusinessVentures/CEO/Documents/AppNote15_High_Density_Stacks.pdf

[3] Rob Coppinger, "High-power diode lasers: Stacking for success", Electro Optics Aug/Sept 2013, https://www.coherent.com/downloads/EOAug2013.pdf

[4] Jörg Neukum, "High-power diode-laser modules and their applications", DILAS the diode laser company, Workshop at World of Photonics 2007, http://passthrough.fw-notify.net/static/620127/downloader.html

6 Appendix

http://www.focuslight.com.cn/administrator/img/201410171212829994.pdf

FOCUSLIGHT

Specification

Module Type [1]	Units	FL-GS02-N*1-X-#			
Operation Mode		QCW			
Pulse Width	us	≤500			
Duty Cycle	%	≤2			
Bar Pitch	mm	0.45, 0.75, 1.15			
Expected Lifetime	shots	10G			
Weight	g	≈16(12bar)			
Optical Parameters [3,5]					
Center Wavelength λ	nm	808		9xx	
Wavelength Tolerance	nm	±3		±5	
Output Power/bar [2]	W	100 ~ 400			
Number of Bars	-	2~12	13~40	2~12	13~40
Spectral Width FWHM	nm	≤4		≤6	
Spectral Width FW90%E	nm	≤6		≤8	
Fast Axis Divergence(FWHM)	°	35			
Slow Axis Divergence (FWHM)	°	8			
Fast Axis Divergence with collimation	°	≤5			
Polarization Mode	-	TE/TM			
Wavelength Temp. Coefficient	nm/℃	~0.28		~0.33	
Electrical Parameters [3,5]					
Operating Current I_{op}	A	100 ~ 420			
Threshold Current I_{th}	A	≤40			
Operating Voltage/bar V_{op}	V	≤2			
Slope Efficiency/bar	W/A	≥1.1			

http://www.quantel-laser.com/en/products/item/conduction-cooled-qcw-stacked-array-.html

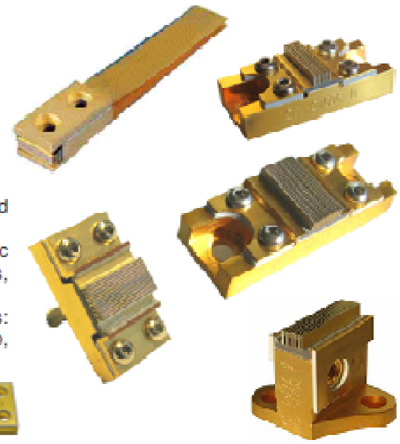
Quantel laser diodes

Conduction-cooled QCW Stacked Array

QD-Q1yzz-A / QD-Q1yzz-B / QD-Q1yzz-BS / QD-Q1yzz-G / QD-Q1yzz-K

DESCRIPTION

QD-Q1yzz-A, QD-Q1yzz-B, QD-Q1yzz-BS, QD-Q1yzz-G and QD-Q1yzz-K are a variety of conductively cooled laser diode stacked arrays. These Stacks can be built from 1 to 19 diode bars of 60W QCW to 400W QCW.
The laser diode bar arrays benefit from a fully mastered technology, with the appropriate design for improved efficiency and reliable operation.
Packaging and heat-sink have been optimized to reduce the overall thermal resistance. Assembly in a compact and rugged package, using AuSn hard solder, allows easy connection to a heat exchanger to get good thermal control.
This technology of stacks has been successfully submitted to specific environmental tests requested for Space missions (long life-tests, endurance under vacuum, irradiations…) with NASA or ESA.
These stacks are ideal for different applications under severe conditions: pumping rods or slabs solid state lasers, illuminators...for aerospace, industrial, space applications.



MAIN FEATURES

- QCW operation
- 60W to 400W QCW per diode bar
- Standard wavelength: from 790 to 980 nm
- Vacuum qualified technology
- Low thermal resistance assembly
- Mechanically robust, shock and vibration resistant

x =	1	2	3	4	5	6			
λ	808	790	830	915	940	980			nm
y =	2	3	4	5	6	7	8	9	
P/bar	60	80	100	125	150	200	300	400	W

SPECIFICATIONS

PARAMETERS @ 25°C	QD-Qxyzz-A	QD-Qxyzz-B	QD-Qxyzz-BS	QD-Qxyzz-G	QD-Qxyzz-K	Units
Number of Diode bars zz =	2 to 06	1 to 12	1 to 19	1 to 16	1 to 08	
Pitch between diode bars	330 to few 1000s					µm
Emitting area	10 x (zz – 1)* pitch					mm²
QCW Optical Power per Diode Bar	up to 400					W
QCW Optical Power	up to 2 400	up to 4 400	up to 7 000	up to 6 000	up to 1 600	W
Operating current @ 100W / bar	95 A Typical - 115A Max					A
Operating current @ 200W / bar	185 A Typical - 215A Max					A
Operating current @ 400W / bar	370 A Typical - 390A Max					A
Operating voltage	<2 V /bar					V
Total efficiency	58% @ 808 nm, 65% @ 940/980 nm					%
Wavelength	790 to 980					nm
Spectral width (FWHM)	3					nm
Beam divergence (FWHM)	9 X 36					deg.

Note :

- Standard Polarisation: TM or TE mode @ 808 nm, TE @ 9xx nm
- Variation of wavelength with temperature is approximately 0.26 nm/°C
- Tolerance on wavelength is +/- 3nm, +/- 1,5 nm on demand
- Double or Triple Quantum Well bars available (ex: 400W @ 200A & 4V)
- Specifications are for nominal lifetime > 1. 10^9 pulses (for 200µs pulse width)

Quantel Laser Diodes reserves the right to change specifications without prior notice

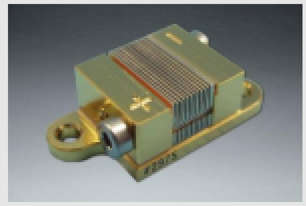
Dsmk-8016 (ed11)

http://www.dilas.com/pages/products.php?category=16&series=7

9xxnm, Conduction-Cooled, QCW, Uncollimated Vertical Diode Laser Stack

DILAS
The diode laser company.

Features
- Low vertical height
- Compact size
- Also available in AuSn solder technology



Device Specification

Optical Parameters[1]	Units		QCW	
Center Wavelength Range[3]	nm		9xx	
Center Wavelength Tolerance	nm	±3	±3	±3
Output Power per Bar[2, 5]	W	100	150	300
Number of Bars[3]	#	6 to 20	6 to 20	6 to 20
Bar-to-Bar Spacing	mm	>0.4	>0.4	>0.4
Spectral Width (FWHM)	nm	<5	<5	<5
Slope Efficiency per Bar	W/A	>1.00	>1.00	>1.10
Fast-Axis Divergence	degree	75	75	75
Slow-Axis Divergence	degree	<10	<10	<10
Wavelength Temp. Coefficient	nm/°C	0.31-0.38	0.31-0.38	0.31-0.38
Electrical Parameters[1, 5]				
Power Conversion Efficiency	%	>50	>50	>55
Threshold Current (I_{TH})	A	<15	<15	<22
Operating Current (I_{OP})	A	<120	<170	<300
Operating Voltage per Bar (V_{OP})	V	<2	<2	<2
Thermal Parameters				
Operating Temperature Range[3,4]	°C	+20 to +45	+20 to +45	+20 to +45
Storage Temperature Range[4]	°C	0 to +55	0 to +55	0 to +55
Recommended Heatsink Capacity per Bar	W	>20	>20	>30

http://www.hamamatsu.com/eu/en/product/category/1001/1007/L11398-16P980/index.html#1328440494403

High-power Laser Diode Bar Module L11398-16P980

Data sheet [160 KB/PDF]

With their emitting areas arranged in line to make a linear array, LD bar modules achieve high performance, high output power and high reliability when coupled with cooling devices. When stacked, the output power can be as high as a few kilowatts. There are primarily three cooling methods: the compact and simple Peltier-type Open Heatsink(OHS); the more efficient Water cooling, and Hamamatsu's original Funryu cooling (highest cooling efficiency). The appropriate cooling method should be selected in accordance with the required output power, driving conditions, and application. Fiber output modules are also available.

Request info | Save to list

· Spec | · Radiant Output Power vs. Forward Current (Typ) | · Typical Emission Spectrum | · Dimensional Outline (Unit:mm) |

Disclaimer [66KB/PDF]

Saved items

Save up to 5 product pages on this list to view again later.

Recently viewed items

L11398-16P980 High-power Laser Diode Bar Module

L11396-50P808 High-power Laser Diode Bar Module

› Delete all

Spec

Type number	L11398-16P980
Type	Pulsed Stack Modules
Peak emission wavelength min.	975 nm
Peak emission wavelength typ.	980 nm
Peak emission wavelength max.	985 nm
Pulsed r adiant power typ.	1600 W
Spectral radiation half bandwidth typ.	4 nm
Operating current typ.	100 A
Operating voltage typ.	× 32 V
Beam spread angle _parallel typ.	× 10 °
Beam spread angle _vertical typ.	× 40 °
Lasing t hreshold c urrent typ.	15 A
Stack pitch	0.4 mm
Max. number of stack	16

http://catalog.cuttingedgeoptronics.com/item/high-power-laser-diodes/laser-diodes/arr179p500hds5

CEO Home About CEO Products Distributors Service Papers Trade Shows Careers Contact CEO

Item # ARR179P500HDS5, High Density Stack

Request Information | Customize Laser Diode

Printable Page | Download PDF | Email This Page

CEO has combined its novel packaging capabilities with its high power QCW laser diode bars to create conductively-cooled laser diode arrays with power densities approaching 25 kW/cm2. These High Density Stack (HDS) arrays are excellent candidates for small, lightweight applications which require maximum diode intensity in the smallest possible area. These arrays are available over a wide range of standard wavelengths, and can be packaged on nearly all CEO laser diode array platforms, including G, Cs, and Derringer packages. This package is also available with mini-bars that are less than 1 cm in length.

Golden Bullet (hard solder) 5-bar mini G Package option is shown.

PUBLIC SUBMISSION

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Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0018
Comment on DOS-2015-0027-0001

Submitter Information

Name: Anonymous Anonymous

General Comment

Discussion on Proposed Category XII(c)(2).

Note: The complete comment appears in the uploaded Word file, Category XII Comments IRFPA F, and the Word attachments
1-3. Only half attachment 4 for the Bosch LRR3: 3rd generation Long-Range Radar Sensor could be uploaded.
but it can be found on internet.

The rule should be revised because it is too general, using wavelength as the only performance parameter. Wavelength
alone is inadequate to define a military IRFPA. From the beginning of ECR, much has been made of the need
to establish a clear bright line between civil and military products, and their corresponding controls. A control using
wavelength as its sole performance parameter cannot succeed in drawing a clear bright line that accurately describes
IRFPAs which warrant control on the USML and those in widespread commercial use.

IRFPAs Captured by (c)(2) are in normal commercial use in a broad range of civil applications, and are available from many
countries. As was noted in the Bureau of Industry and Security's report Critical Technology Assessment: Night Vision Focal
Plane Arrays, Sensors, and Cameras, (October 2012) the commercial market for IRFPAs is growing by leaps and bounds

with a growing diversity of international suppliers. For example, as can be seen in Attachment 1, Zenics (a Belgian company)
provides high-sensitivity, cooled, InGaAs IRFPAs, recommended by the manufacturers for night vision applications as a
commercially available product. Xenics also has a large assortment of uncooled lower sensitivity InGaAs IRFPAs available
for various commercial uses (Attachment 2). Some InGaAs IRFPAs on the Xenics website are advertised as dual use,
non-ITAR cameras. Similar IRFPAs are available from companies in Taiwan (Attachment 3) and many other countries.
The existence of these IRFPAs shows that many IRFPAs are true dual-use technologies of the sort the Commerce Control
List was created to hold. The USML is best suited for true military-only technology.

As mentioned above, a principal goal of ECR is a well-defined bright line between military and non-military technologies.
Unfortunately, as proposed (c)(2) captures almost all IRFPAs with the stated spectral range without regard to whether they
are sensitive enough to actually be used to detect the low signals required of night vision detectors. As should also be clear
from above discussion the technology to make InGaAs devices is in widespread use in civil commercial applications, is
definitely not unique to the USA, and should not be considered a crown jewel technology. Placing ITAR controls on InGaAs
IRFPAs as a class, without greater technical specification to separate military systems from those in ordinary commercial use,
will do nothing to prevent anyone outside the United States from acquiring the technology. It will, however, further savage the
U.S. industrial base.

If on additional review it proves impractical to adequately define the bright line between civil and military products, alternative
options utilized elsewhere in ECR, that could be adapted for use with IRFPAs include a revision to exclude IRFPAs used in
civilian LIDAR, including civil automotive LIDAR. In the alternative, conforming controls on IRFPA to similar usage in the
Wassenaar Agreement Munitions List, and in other ITAR categories revised under Export Control Reform, it could control
only those IRFPAs specially designed for military applications. If the government determines that these carve outs are too
broad, that only serves to highlight the importance of more carefully defining the performance criteria that defines the bright
line between civil and military IRFPAs.

Proposal for Revised Language.

Amend the Note to paragraph (6)(6) by striking 200 and replacing it with 250.

Amend the Note 1 to paragraph (c)(2) to include the clause: IRFPAs used in automotive or civilian LIDAR are not subject to the ITAR.

Add a Note to paragraph (e)(3) stating Paragraph (e)(3) does not control wafers incorporating structures for a ROIC
specially designed for civil automotive LIDAR.

Amend the Note to paragraph (e)(4) adding a statement that ROICs specially designed for civil automotive LIDAR are not
controlled by paragraph (e)(4).

Add a Note to Paragraph (e)(5) stating Paragraph (e)(5) does not control ROICs specially designed for civil automotive
LIDAR.

Alternative Language for Paragraph (c)(2).

Amend paragraph (c)(2) to read: Photodetector, microbolometer detector, or multispectral detector IRFPAs specially
designed for military applications and having a peak response within the wavelength range exceeding 900nm but not
exceeding 30,000 nm

Attachments

Category XII Comments IRFPA F

Attachments 1

Attachments 2

Attachments 3

Attachments 4 h

Category XII Comments

Discussion on Proposed Category XII(c)(2).

The rule should be revised because it is too general, using wavelength as the only performance parameter. Wavelength alone is inadequate to define a military IRFPA. From the beginning of ECR, much has been made of the need to establish a clear "bright line" between civil and military products, and their corresponding controls. A control using wavelength as its sole performance parameter cannot succeed in drawing a clear bright line that accurately describes IRFPAs which warrant control on the USML and those in widespread commercial use.

In general, the proposed control in (c)(2) corresponds to only one point in an eight-dimensional space which defines the universe of IRFPAs; military IRFPAs separated by one or more seven dimensional surfaces from commercial IRFPAs (a red surface the analog of the ECR red line). In fact, it takes at least eight parameters to adequately characterize the performance capabilities of an IRFPA (pixel pitch, pixel format, dark current, temperature of operation, quantum efficiency at the critical wavelengths, fill factor, input capacitance and response frequency). Only IRFPAs which pass certain performance thresholds in each parameter are militarily useful. Many IRFPAs which fall below the threshold of military grade nevertheless have significant civil uses. Under the proposed rule, however, IRFPAs which have poor performance in any of these parameters, and which might well be completely useless for almost any application, would still be captured as defense articles. For IRFPAs whose parameters are not within the space defined by these eight parameters as military grade, ITAR control is overbroad. For those IRFPAs whose performance in these eight parameters is so poor as to make them useless, ITAR control is ludicrous.

More specifically, the focus of this comment is on IRFPAs operating in the 900 to 1700 nm spectrum which are associated with civil collision avoidance LIDAR using InGaAs IRFPAs which are captured under the proposed Category XII(c)(2). We urge the Directorate of Defense Trade Controls ("DDTC") to craft a control which fosters development of U.S. industry to meet widespread commercial demand for IRFPA as components in civil LIDAR systems, including civil automotive collision avoidance systems. We strongly believes that this can be accomplished by either drafting a control based upon the eight above identified performance criteria, or by broadening the carve out for specific civil use cases within Note 1 to paragraph (c)(2). Other portions of the proposed rule are also overbroad as drafted, including controls on readout integrated circuits in (e)(3), (e)(4) and (e)(5). We believe that the excessive breadth of these provisions can be partially cured by a more precisely defined control in (c)(2) IRFPAs, but it would be helpful to clarify in a Note to paragraph (e)(3) that "Paragraph (e)(3) does not control wafers incorporating structures for a ROIC specially designed for civil automotive LIDAR." Similarly, the Note to paragraph (e)(4) should add a statement that "ROICs specially designed for civil automotive LIDAR are not controlled by paragraph (e)(4)." A new Note to Paragraph (e)(5) should state "Paragraph (e)(5) does not control ROICs specially designed for civil automotive LIDAR."

It is worth noting that the control implicitly recognizes that (c)(2) is overbroad, in that Note 1 to Paragraph (c)(2) excludes IRFPAs based upon certain materials. While marginally helpful, this material-based carve out is insufficient to adequately characterize the eight parameter performance criterion of an IRFPA's capability.

In addition to more precisely defining the eight relevant performance criteria that define military IRFPAs, we urge DDTC to consider foreign availability. ITAR controls on U.S.-origin components that are widely available from many countries around the world, including those which do not share U.S. foreign policy and national security objectives, cannot be effective in denying foreign access to the technology. Where the technology is in widespread civil use, ITAR controls compound the competitive harm to U.S. manufacturers by creating enormous legal risks for manufacturers and potential customers alike, but with no corresponding national security benefit.

IRFPAs Captured by (c)(2) are in normal commercial use in a broad range of civil applications, and are available from many countries. As was noted in the Bureau of Industry and Security's report "Critical Technology Assessment: Night Vision Focal Plane Arrays, Sensors, and Cameras," (October 2012) the commercial market for IRFPAs is growing by leaps and bounds with a growing diversity of international suppliers. For example, as can be seen in Attachment 1, Zenics (a Belgian company) provides high-sensitivity, cooled, InGaAs IRFPAs, recommended by the manufacturers for night vision applications as a commercially available product. Xenics also has a large assortment of uncooled lower sensitivity InGaAs IRFPAs available for various commercial uses (Attachment 2). Some InGaAs IRFPAs on the Xenics website are advertised as dual use, non-ITAR cameras. Similar IRFPAs are available from companies in Taiwan (Attachment 3) and many other countries. The existence of these IRFPAs shows that many IRFPAs are true dual-use technologies of the sort the Commerce Control List was created to hold. The USML is best suited for true military-only technology.

For civil automotive applications, industry is producing solid state collision avoidance and navigation LIDAR which, under the proposed Note to paragraph (b)(6), will not be subject to the ITAR provided their range is limited to 200 meters. This range should be extended to 250 meters, because this is the range of competitive automotive radar (Attachment 4). Additionally, these components for civil automotive LIDAR use FPAs that operate in 900 – 1700 nm range that are captured by the proposed (c)(2) even when the FPA is poorly adapted for military night vision applications. IRFPAs used in civil automotive LIDAR applications are components of commercial machine vision devices, not night vision devices. Note eye-safety is an FDA requirement for civil laser systems (limited exemptions are available for military products), and that FDA requirement is the basis for use of IRFPAs in automotive applications. An IRFPA in the 900-1,700 nm spectral range is used to detect the reflected light from civil LIDAR lasers (the laser is similar to a flash bulb in an ordinary camera) because the laser intensity needed to achieve collision avoidance distances is eye-safe in this spectral range but not eye-safe at shorter wavelengths not captured by (c)(2).

Similarly, a multi-pixel FPA is needed to distinguish, for example, pedestrians from moving vehicles. This is not efficiently done with one pixel or even a few pixels when scanned over the camera field of view due to image distortion. ITAR controls on components utilized in these civil automotive systems will hinder other governmental priorities, such as automotive safety. Over 30,000 Americans die on US highways each year and more than 1,000,000 die on highways worldwide. Many of these casualties will be avoided in the future by the increasingly widespread adoption of civil automotive crash avoidance and navigation systems based upon IRFPAs. Because of the worldwide need, the automotive application is also a large and lucrative emerging market for American business.

As mentioned above, a principal goal of ECR is a well-defined bright line between military and non-military technologies. Unfortunately, as proposed (c)(2) captures almost all IRFPAs with the stated spectral range without regard to whether they are sensitive enough to actually be used to detect the low signals required of night vision detectors. As should also be clear from above discussion the technology to make InGaAs devices is in widespread use in civil commercial applications, is definitely not unique to the USA, and should not be considered a crown jewel technology. Placing ITAR controls on InGaAs IRFPAs as a class, without greater technical specification to separate military systems from those in ordinary commercial use, will do nothing to prevent anyone outside the United States from acquiring the technology. It will, however, further savage the U.S. industrial base.

If on additional review it proves impractical to adequately define the bright line between civil and military products, alternative options utilized elsewhere in ECR, that could be adapted for use with IRFPAs include a revision to exclude IRFPAs used in civilian LIDAR, including civil automotive LIDAR. In the alternative, conforming controls on IRFPA to similar usage in the Wassenaar Agreement Munitions List, and in other ITAR categories revised under Export Control Reform, it could control only those IRFPAs "specially designed" for military applications. If the government determines that these carve outs are too broad, that only serves to highlight the importance of more carefully defining the performance criteria that defines the bright line between civil and military IRFPAs.

<u>Proposal for Revised Language</u>.

Amend the Note to paragraph (6)(6) by striking "200" and replacing it with "250".

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Add a Note to Paragraph (e)(5) stating "Paragraph (e)(5) does not control ROICs specially designed for civil automotive LIDAR."

<u>Alternative Language for Paragraph (c)(2).</u>

Amend paragraph (c)(2) to read: "Photodetector, microbolometer detector, or multispectral detector IRFPAs specially designed for military applications and having a peak response within the wavelength range exceeding 900nm but not exceeding 30,000 nm…"

Attachment 1

Preliminary

Xenics

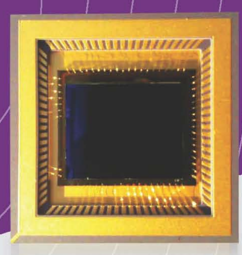
Infrared Solutions

Imagine the invisible

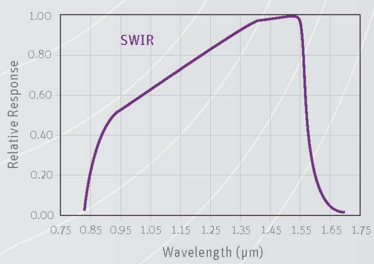
Modules & components

XFPA-1.7-640-LN2

LN2 cooled high resolution SWIR detector



Designed to have the lowest noise and highest sensitivity for low-light-level measurements



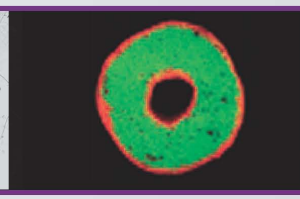
The XFPA-1.7-640-LN2 excels in performance for any R&D spectroscopy or semiconductor failure analysis task. These demanding applications, where very low light levels need to be measured, require image sensors with low dark current, low noise and best responsitivity in the SWIR range. All of these features are now combined in one single device.

The in-house developed InGaAs detector XFPA-1.7-640-LN2 is optimized for 77K operation, using Liquid Nitrogen (LN2) cooling and is based on a SFD (Source Follower per Detector) read-out topology for ultra-low noise levels ever seen (<20 e-). Additionally, a very low dark current of less than 5e-/pixel allows for integration times of several hours.

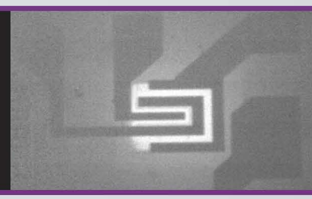
The high resolution 640 x 512 InGaAs detector with 20 μm pixel pitch features a maximum full frame rate of 2.5 Hz. The frame rate can be increased when a smaller region-of-interest is selected. A non-destructive read-out mode simplifies operation when long integration times are used.

Designed for use in

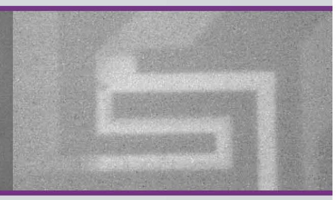
Astronomy



Lab spectroscopy



Photon emission 10x zoom



Photon emission 20x zoom

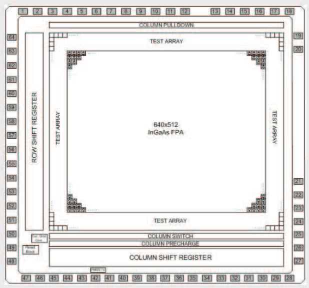
Applications

- Astronomy
- Raman spectroscopy
- Low light level SWIR & VisNIR imaging
- High resolution imaging spectroscopy
- Failure analysis via photon emission or electro-luminescence

Benefits & Features

- Lowest noise
- High sensitivity
- Low dark current
- Extreme long integration time
- Measuring extreme low light signals
- Extending SWIR imaging to the visible

Sensor architecture



Specifications

Array Specifications	XFPA-1.7-640-LN2
Array characteristics @ 77K	
Array type	InGaAs
Spectral band	Standard 0.85 to 1.6 µm; optional: 0.4 to 1.6 µm
# pixels	640 x 512
Pixel pitch	20 µm x 20 µm
FPA cooling	LN2
Full frame rate	2.5 Hz (4 output mode)
# outputs	1 or 4 selectable
Integration time	up to 24 hours
Pixel operability	> 98 %
Detector characteristics @ 77 K	
Peak sensitivity wavelength	1.5 µm
Peak Quantum Efficiency	> 80 %
Windowing	Yes
ITR and IWR	Yes
Operating temperature range	77 - 300 K
Pixel clock frequency	20 kHz or 250 kHz
Power consumption	2 Watt
Supply voltage	3.3 V
Gain (e-/ADU count)	2.2 µV/e-
Pixel Well Depth	400 000 e-
Noise	< 20 e-
Dark current	< 5 e-/sec per pixel
Dynamic range	100 dB

Product selector guide

Part number	# Pixels	Pixel size (µm^2)	Cooling	VisNIR option
ASY-008083	640 x 512	20	LN2	No
ASY-008084				Yes

www.xenics.com
www.sinfrared.com

Xenics Headquarters
Ambachtenlaan 44, BE-3001 Leuven, Belgium
T +32 16 38 99 00 • sales@xenics.com

Xenics
Infrared Solutions
ISO 9001:2008 certified

Attachment 2

Xenics
Infrared Solutions

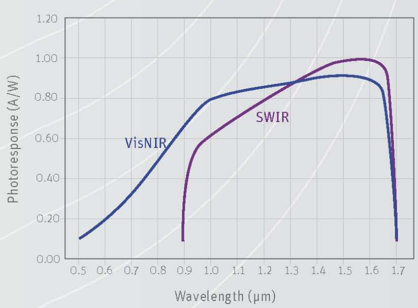
Imagine the invisible

Modules & components

XSW-640

High resolution
TE1-stabilized SWIR OEM module

Ready-to-integrate SWIR OEM module consuming ultra-low-power



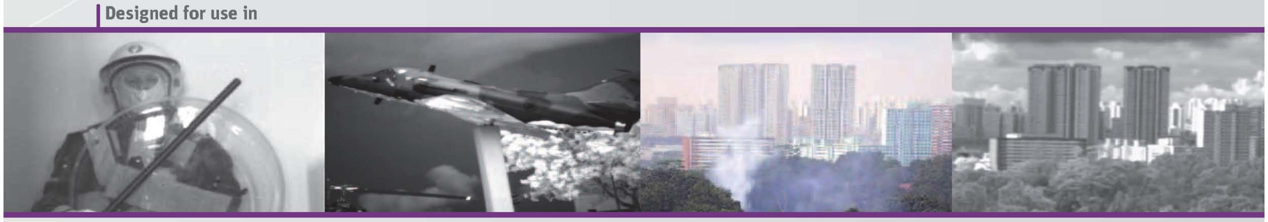
Xenics' XSW-640 OEM module is extremely compact and versatile for easy and swift integration in your SWIR imaging configuration.

Typical OEM applications include infrared imaging for man–portable and unmanned (airborne and land-based) vehicle payloads, night vision, border security, Search & Rescue (SAR) and more.

The XSW-640 OEM module detects short wave infrared radiation between 0.9 (optionally 0.4) and 1.7 µm with a wide dynamic range and wide operating temperature.

The Thermo Electric (TE) stabilization reduces the dark current and noise levels. Together with on-board image processing you will have best contrast and high image quality.

Designed for use in



Person identification — Camouflage detection — Vision enhancement: looking through haze with SWIR

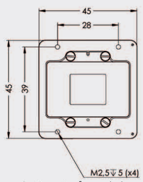
Key features

- Made in Europe
- High resolution
- Easy connectivity
- Small 20 µm pixel pitch

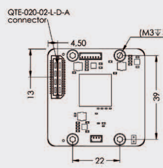
OEM applications

- SWIR sights
- UAV / UGV
- Border security
- Laser detection
- Night vision (passive & active)
- Search & Rescue
- Driver assistance
- Electro optical payloads
- Long range identification
- Enhanced Vision Systems (EVS)

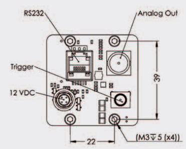
Ready-to-integrate



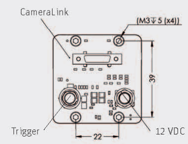
Front of module



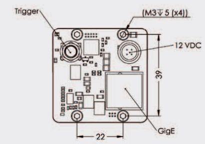
Samtec QTE interface



Analog interface



CameraLink interface



GigE interface

Specifications

Module specifications	XSW-640-Samtec	XSW-640-Analog	XSW-640-CL	XSW-640-GigE
Lens				
Focal length	Broad range of lenses optional available			
Optical interface	Fixation holes for multiple lens mount			
Imaging performance				
Frame rate	Max 100 Hz	25 Hz (PAL) 30 Hz (NTSC)	Max 100 Hz	
Window of Interest	Minimum size 32 x 4			
Exposure time range	1 µs - 40 ms in high gain mode			
Noise*	High gain: 120 e- Low gain: 400 e-			
Gain	High gain mode: 1.28 e-/ADU Low gain mode: 16.2 e-/ADU			
On-board image processing	Image correction (TrueNUC for high gain and low gain), auto gain, auto exposure, histogram equalization, trigger possibilities			Up to 4 NUCs, auto gain, trigger possibilities
ADC	14 bit			
Interfaces				
Digital output	BT.601-6/ BT.656-5	-	CameraLink or Xeneth API/ SDK	GigE Vision or Xeneth API/SDK
Analog output	-	PAL or NTSC	-	-
Module control	Serial LVCMOS 3 V (XSP)	RS232 (XSP)	CameraLink	GigE Vision
Trigger	In or out (configurable)			
Power requirements				
Power consumption* (without TEC)	2.5 W	3 W	2.8 W	4 W
Power supply	+/- 12 V			
Physical characteristics				
Shock	40 G, 11 ms halfsine profile, according to MIL-STD810G			
Vibration	5 G, (20 Hz to 1000 Hz), according to MIL-STD883J			
Operating case temperature	-40 °C to 70 °C (industrial components)			
Storage temperature	-45 °C to 85 °C (industrial components)			
Dimensions (W x H x L mm³)	45 x 45 x 51	45 x 45 x 55	45 x 45 x 55	55 x 55 x 65
Weight module (without lens)	120 g	145 g	129 g	165 g

** Typical values*

Array specifications	XSW-640
Sensor type	InGaAs Focal Plane Array (FPA) ROIC with CTIA** topology
Spectral band	0.9 to 1.7 µm Optional 0.4 to 1.7 µm (VisNIR)
# pixels	640 x 512
Pixel pitch	20 µm
Readout mode	Integrate Then Read (ITR) Integrate While Read (IWR)
Quantum efficiency	80 % @ 1.6 µm (SWIR) 85 % @ 0.9 µm (VisNIR)
ROIC noise*	High gain: 60 e-; low gain: 400 e-
Sensitivity*	High gain: 20 µV/e-; low gain: 1.6 µV/e-
Dark current*	0.8 x 10^6 e-/s
Integration capacitor	High gain: 6.7 fF; low gain: 85 fF
Array cooling	TE1-stabilized
Pixel operability	› 99 %

** Typical values*
*** Capacitor TransImpedance Amplifier*

Product selector guide

Part number	Frame rate	Interface	VisNIR
XEN-000295*	100 Hz	16bitDV	No
XEN-000304**		BT.656	
XEN-000343		CameraLink	
XEN-000341		GigE Vision	
XEN-000347	25 Hz	PAL	
XEN-000348	30 Hz	NTSC	
XEN-000098*	100 Hz	16bitDV	Yes
XEN-000305**		BT.656	
XEN-000344		CameraLink	
XEN-000342		GigE Vision	
XEN-000349	25 Hz	PAL	
XEN-000350	30 HZ	NTSC	

Part number	Interface	Connects with	Optional
ASY-000880*	CameraLink	XEN-000295 XEN-000098	Yes
ASY-000879**	PAL/NTSC	XEN-000304 XEN-000305	

** and **Optional test board interface*

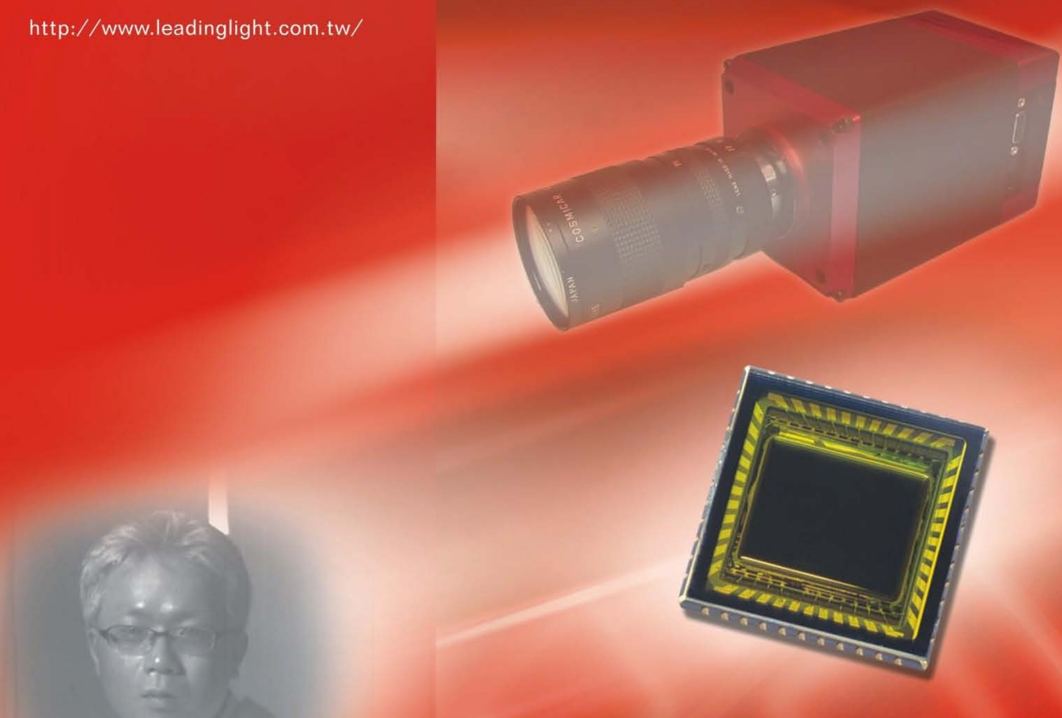
www.xenics.com
www.sinfrared.com

Xenics Headquarters
Ambachtenlaan 44, BE-3001 Leuven, Belgium
T +32 16 38 99 00 • sales@xenics.com

Xenics Infrared Solutions
ISO 9001:2008 certified

Attachment 3

http://www.leadinglight.com.tw/



InGaAs FPA 320x256

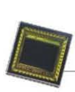
The InGaAs focal plane array is the optimized solution for near-infrared imaging and imaging spectrography applications in 900nm to 1700nm wavelength range especially under uncooled condition. The core technology of CLPT implements the InGaAs FPA with excellent quality. The CLCC package also facilitates the mechanical design of CCD and CMOS camera vendors.

Features

- 320x256 array format
- 30um pixel pitch
- CLCC package
- Low dark current
- High quantum efficiency
- High operability

Applications

- Near-infrared imaging
- Hyper spectrum
- Covert surveillance
- Semiconductor inspection
- Astronomy and scientific
- Industrial thermal imaging



中華電信股份有限公司 Chunghwa Telecom Co., Ltd.

中華立鼎光電 Chunghwa Leading Photonics Tech.

InGaAs FPA 320x256

Specifications of FPA 320x256-C

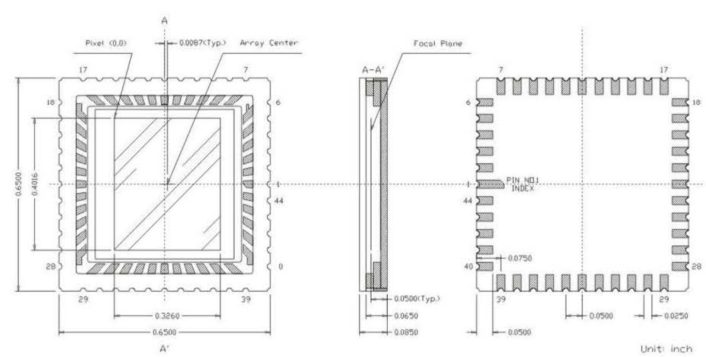
Absolute Maximum Ratings

Parameter	Unit	Min	Max
Operation Temperature	°C	-20	85
Storage Temperature	°C	-40	85
Power Consumption	mW	---	175

FPA Characteristics

Parameter	Typical	Conditions
Spectral response	0.9um-1.7um	---
Minimum Pixel Operability	>99%	Within 318x254 center region
Dark current	<0.4pA	25°C,0.1V detector bias
Quantum efficiency	>70%	λ=1.0um-1.6um
Detectivity	≧5x10[11] Jones	25°C, λ=1.55um,T_{int}=16ms,High Gain
Response nonumiformity	<10%	under 50%saturation,25°C
Nonlinearity(max.deviation)	<2%	Over 10%-90% full well capactity
Max.pixel rate	10MHz	---
GAIN	High:14.38uV/e^- Low:0.77uV/e^-	25°C

Package Outline



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Technical features	
Frequency range	76...77 GHz
Distance	0.5...250 m
Accuracy	±0.1 m
Relative speed	-75 ...+60 m/s
Accuracy	±0.12 m/s
Vision range	
Horizontal opening angle	30° (-6 dB)
Vertical opening angle	5° (-6 dB)
Modulation	FMCW
Max. number of detected objects	32
Operating temperature	-40 °C...+85 °C (periphery)
Vehicle connector	MQS 8 Pins
Cycle time (incl. auto diagnosis)	typically 80 ms
Dimensions (H x W x D)	77 mm x 74 mm x 58 mm
Weight	285 g
Power consumption	typically 4 W
ISO certification	ISO 15622 Class IV sensor

Sensor architecture

The LRR3 sensor is a monostatic Frequency Modulated Continuous Wave (FMCW) radar with four fixed beams. An important aspect of the sensor architecture is the high level of integration for the RF-functionality as well as for the sensor control unit and the signal processing. This results in a highly reliable and compact sensor. We use cost-effective, fully silicon based technology for the RF-components. Innovative signal processing algorithms allow excellent measurement performance and the handling of complex traffic situations such as a "lane free detection" by angular separation of objects. Our dedicated safety concept guarantees the compatibility of the sensor with safety relevant applications.

The sensor consists of two PCBs:

- The RF-module contains the RF-circuitry (SiGe-MMICs) and the Radar-ASIC with integrated modulation control and the signal pre-processing (pre-amplification, A/D conversion, filtering).
- The sensor control unit contains the microcontroller, the System-ASIC and optionally a FlexRay transceiver. The integrated sequencer takes over control tasks of the radar sensor. This enables the handling of new signal processing algorithms by the microcontroller as certain time consuming task schemes are outsourced and taken over by the Radar-ASIC. The microcontroller has been developed especially for driver assistance systems. The System-ASIC forms an essential part of the safety concept. It provides the power supply and contains the CAN interfaces.

Sensor performance

The LRR3 sensor exhibits a combined patch lens antenna which is well suited for large frequency ramps allowing a high resolution in distance. Its advanced antenna design enables a detection range of 0.5 up to 250 m with a field of view of 30°. The field of view can be customized to an opening angle up to 45° by modifying the aperture of the lens. LRR3 provides excellent measurement accuracy of angle, velocity and distance as well as object separation.

Applications

The LRR3 is the centerpiece of the automatic distance and speed control system ACC (Adaptive Cruise Control) and Predictive Emergency Braking Systems. ACC and the Predictive Emergency Braking Systems network the radar sensor with the ESP® system.

ACC uses information from the long-range radar sensor to control the vehicle's speed by automatically braking and accelerating so that it maintains at a predefined minimum distance from the preceding vehicle.

Our Predictive Emergency Braking Systems continuously monitor the situation in front of the vehicle and trigger appropriate collision avoidance/mitigation measures in critical situations. They support the driver with an intelligent predictive warning concept and also provide effective emergency braking assistance in critical situations. If a collision is unavoidable, the system automatically triggers emergency braking in order to reduce the risk of injury.

Via intelligent networking of our radar sensor with components and systems installed in the vehicle or by integrating information of other sensors such as a camera or additional radar sensors we enable new applications or enhancements of existing functions. Through the use of multiple sensors and components we further increase the safety of vehicle occupants and other road users without increasing cost. Bosch collects this networking of components and systems under the name CAPS – Combined Active Passive Safety.

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Submitter Information

Name: Anonymous Anonymous

General Comment

General Comment: Category XII

The Export Control Reform (ECR) initiative was launched with an express purpose of drawing a clear demarcation, a reline,
between truly military technology and commercial technology with military capabilities. As described by Secretary Gates, this
was principally important for national security, but it has important implications for industry as well. The value of this reline to
the American economy is the support of our commercial technology base by allowing American technology to compete with
foreign products globally without the risk, expense and taint of ITAR controls. The rewrite of Category XII fails its goals by a
wide margin and should be fundamentally rewritten. The revised Category XII both fails to focus on truly military technology
and also captures items in widespread commercial use available from numerous countries which operate outside of the
multilateral regimes. Such overbroad controls will do little to restrict access by our adversaries, but will do much to lock U.S.
suppliers out of the international marketplace.

A reline should be driven by a parameter set whose values separate military performance from commercial performance. In
addition those items which are widely available internationally and currently sold commercially should, in the main, be on the
commercial side of the redline. Unfortunately it does not appear that an effective effort was made

by the government in
drawing technically reasonable relines or in simply researching the internet for commercial products available internationally.
A particularly egregious example is apparently infrared focal plane arrays (IRFPAs). IRFPAs used in a variety of commercial
and military imaging systems, are controlled by only one parameter, the wavelength of light (the color of light) in Category
XII (c)(2). This is not well reasoned.

Consider the result if a company took this approach in responding to a request for proposals from any military force anywhere
in the world. If a commercial company were to respond to a solicitation for a military imaging system by arguing that just
because their proposed system responds in some arbitrary way to the proper wavelength of light that it would be suitable for
contract award, the proposal would be thrown in the trash amid peals of laughter. Clearly there are many more performance
parameters that define an actual military system. Correspondingly it seems (c)(2) and many other proposed Category XII
rules should be considered embarrassingly shallow by serious technologists. In this case, however, the Category XII rewrite
has dire economic consequences, capturing commercial technology components under the ITAR and should be rewritten.

Apart from the effect of public comments, the citizens of the USA are dependent on the government to develop sensible rules
that both protect us and our economic future. In the case of the Category XII rewrite it clearly takes technical expertise and
an understanding of military systems to develop adequate and sensible rules. However, it takes less skill to research available
technology on the internet and determine what technology is available commercially and also determine what performance is
expected from this technology in years to follow. There is very little evidence that the government has made this effort to test
even its overly simplistic redlines. This is unconscionable for two reasons: (1) Getting the best rule possible should be a
government goal, given the serious economic impact of getting it wrong; (2) Letting many citizens duplicate the research
necessary to respond to the rewrite controls is a waste of our time and resources when one competent government
researcher could have saved us the effort.

Suggested Revision 1: Completely revise the Category XII rewrite using input from the industrial community to help the
government develop the proper performance parameters and their magnitudes.

Suggested Revision 2: Use, Specially designed for military applications in the Category XII controls where the performance
parameter set is complex or militarily sensitive.

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International Traffic in Arms: U.S. Munitions List Category XII; Revision

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Comment on DOS-2015-0027-0001

Submitter Information

Name: Anonymous Anonymous

General Comment

Discussion: Proposed Category XII (c)(2) and (c)(4)-(c)(6)

(c)(4)-(c)(6) proposes to decontrol some of the IRFPAs controlled in (c)(2) if they are in a permanently encapsulated sensor
assembly: in (c)(4), if the IRFPA is less than 256 detector elements (16 x 16 for example); in (c)(5) if IRFPA is a
micobolometer of less than 328,000 detector elements (roughly 573 x 573); in (c)(6) multispectral IRFPAs having a spectral
response below 1500 nm. Apparently the logic behind these decontrols is that a permanently encapsulated sensor assembly
somehow mitigates the illogic of using a single performance parameter, wavelength, to control a system that has at least eight
relevant performance parameters, IRFPAs in (c)(2). These decontrols do not enhance the U.S.As competiveness in overseas
markets and in fact may diminish the security of crown-jewel technologies. It is recommended that these decontrols be
deleted and (c)(2) be modified instead.

Cost, risk and the possibility of investment, with resulting business expansion, are critical business issues. ITAR control of
technology creates very significant legal risks for manufacturers, customers and investors. Due to these legal risks there are
very few commercial investors willing to take a chance on a product containing ITAR components. There are also cost
consequences for manufacturing products including ITAR components. For example, permanently

encapsulated IRFPAs use ITAR controlled readout integrated circuits (ROICs) and ITAR controlled detector arrays. At TSMC, a well-known CMOS foundry, a ROIC wafer produced using an ITAR controlled wafer process costs twice as much as an identical wafer produced using non-ITAR processing. Hence apart from the cost of implementing ITAR procedures and licensing in the manufacture of the sensor assembly, the ROIC is twice the price paid by offshore competitors.

Based on the carve-out language in encapsulated IRFPAs, (c)(4)-(c)(6), crown jewel technologies could be part of a permanently encapsulated sensor assembly . Apparently the encapsulation rationale is that packaging will protect the device from all back-engineering. This is almost certainly not true for all the IRFPAs covered by these rules. A concerted back-engineering effort may only require a piece of the IRFPA and a piece of the associated ROIC to acquire enough information, over time, for experts to reproduce it. A significant back-engineering effort is required but there are countries with the funds, expertise and motivation to try to obtain these most-advanced, American, military technologies. The only way to adequately protect our crown-jewel technologies is to limit access to them and that is ITAR control. Encapsulation carve-outs compromise that technology. It would be far more efficient to distinguish the EAR technology from the ITAR technology as is done in the amendment language proposed below. It is a waste of USG effort and an unnecessary burden on American businesses to control non-ITAR IRFPAs on the EAR, using the semi-ITAR new 600 ECCN series, and inadequately protect crown-jewel military IRFPAs.

Proposed Amendments:

1. Amend paragraph (c)(2) to read: Photodetector, microbolometer detector, or multispectral detector IRFPAs specially designed for military applications and having a peak response within the wavelength range exceeding 900nm but not exceeding 30,000 nm

2. Delete (c)(4)-(c)(6)

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Comment on DOS-2015-0027-0001

Submitter Information

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General Comment

*(b) Lasers, and laser systems and equipment, as follows:

Proposed Rule (b)(9):
Lasers operating at a wavelength exceeding 3,000 nm that provide a modulated output for systems or equipment controlled in Category XI(a)(4);
Comment: This proposed rule may inadvertently cover standard commercial lasers such as the ARIES fixed-wavelength mid-IR laser (http://www.daylightsolutions.com/assets/004/5409.pdf), which has an operating wavelength exceeding 3,000nm and modulation DC-1 MHz. Please clarify. The ARIES laser is available for sale in China from distributor A&P: http://www.anpico.com/en/ProductDetails_43.html.

Proposed Rule (b)(10):
Tunable semiconductor lasers having an output wavelength exceeding 1,400 nm and an output power greater than 1 W;
Question: This proposed rule does not (presumably) cover fixed wavelength broadband sources (50 nm for example), only tunable sources at these wavelengths?

Proposed Rule (b)(11):
Non-tunable single transverse mode semiconductor lasers having an output wavelength exceeding 1,510 nm and either an average output power or continuous wave (CW) output power greater than 2 W;
Question: Does this proposed rule refer to the power from each (single mode) emitter being rated at 2 W, or does it also cover the combining of multiple single mode emitters into one beam?

Proposed Rule (b)(12):
Non-tunable multiple transverse mode semiconductor lasers having an output wavelength exceeding 1,900 nm and either an average output power or CW output power greater than 2 W;
Question: Does this proposed rule refer to the power from an individual multi-mode emitter at this wavelength or does it also cover the combining of many emitters into one beam?

Proposed Rule (b)(14):
Developmental lasers and laser systems or equipment funded by the Department of Defense;
Question: The purpose of the SBIR program is to foster small business commercialization of SBIR-funded technology, so restricting the export of products that result from SBIR funding appears to conflict with this purpose. See https://www.sbir.gov/about/about-sbir. Will this proposed rule apply to SBIR programs that are funded by the Department of Defense?

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Comment on DOS-2015-0027-0001

Submitter Information

Name: Anonymous Anonymous

General Comment

Category XII Comments
Comment on Proposed Category XII (e)(3).
Certain wafers

Comments for Paragraph (e)(3) It reads, Paragraph (e)(3) is added for certain wafers incorporating structures for Read-Out Integrated Circuits controlled in (e)(4) or (e)(5) or for IRFPA detectors controlled in (c)(2). This is too general of a statement. For instance, we use wafers of similar structure for single element devices that are not ITAR restricted. These wafers can be processed to build IRFPAs as well as single element devices. Companies from all over the world have patented or published wafer structures that would be suitable to build IRFPAs. Every fiber to the home network utilizes devices built from wafers that could be used to build IRFPAs. Having control at this level, without using a more descriptive term than certain is terribly short sighted and fails miserably to draw a clear bright line.

Suggestion:
1. Remove entire paragraph and replace with a section that would exempt from the ITAR all single element, 1d, and 2d detectors with less than 100 elements, no pixel size restriction. This would be a clear bright line and allow optical communication companies some room for technical advancement.
2. Add specifically designed for military use to the statement. i.e. Paragraph (e)(3) is added for wafers specifically designed for military use incoporating structures for Read-Out Integrated Circuits controlled in (e)(4) or (e)(5) or for IRFPA detectors controlled in (c)(2)

Comment on Proposed Category XII (f).
Technical data

This section is trying control technical data and my comment is related to wafers. The best quality wafer material is now sourced overseas. We need to supply a structure (technical data) to the manufacturer to grow this wafer. If this rule is not more specific we would not be able to procure wafers in some instances.

Suggestion:
Amend the Note 1 to paragraph (f) to remove, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to ITAR even if the technical data or defense services could also apply to items subject to the EAR.

Comment on Proposed Category XII(c)(2).
(c)(2) captures almost all IRFPAs with the stated spectral range. As I mentioned above, the technology to make InGaAs devices is in the public domain via scientific publications and patents. Placing ITAR controls on all InGaAs IRFPAs will destroy the burgeoning collision avoidance market in the US and will do nothing to prevent anyone outside the United States from acquiring the technology.

Suggestion:
1. paragraph (c)(2) is added for certain photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) specifically designed for military use.

Conclusions
1. This proposal is headed in the wrong direction and should fundamentally be rewritten
2. Specifically designed should be more fully applied to this category.
3. USML should align with the Wassenar Munitions list

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Submitter Information

Name: Anonymous Anonymous

General Comment

Following the Amendment to the International Traffic
in Arms Regulations: Revision of U.S.
Munitions List Category XII

(6) For any criteria the public believes control items in normal commercial use, the public is asked to identify the multilateral controls (such as the Wassenaar Arrangement's Dual Use List), if any, for such items, and the consequences of such items being controlled on the USML.

Taking in exemple the goods that are in section 6 - Sensors and Lasers of the USML, some electro-optics cameras that are already controlled in Wassenaar Arrangement's Dual Use List could be controlled in the USML, will give a disadvantage to foreign companies, who uses U.S. non-ITAR controlled products. The Wassenaar Arrangement's Dual Use List is already being respected and inforced by Canada and the others countries that agreed to it.

In section 6 of the USML, there are a lot of products that are dual-use and are controlled only for a component that could be integrated to a medical camera or a surveillance camera, no matter who the final end-user of the goods could be. Thus, adding another sort of export control like the USML, will negatively impact SMEs in Canada that are selling internationally and abiding to Canada's export control laws. Perhaps there are some goods that are not widely use as commercially as others, but the distinction should be made between a precise type of goods and not only for a complete category in section 6.

Adding paperwork for a USML export license, will mean more hours, more learning programs for a SME that is already juggling with less human power than a big corporation, in a more competitive world. The Wassenaar Arrangement's Dual Use List is sufficient for a export control measure, when using non-ITAR controlled products.

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July 6, 2015

Office of Defense Trade Controls Policy
U.S. Department of State
Via Email: DDTCPublicComments@state.gov

Subject: ITAR Amendment – Category XII

To Whom It May Concern:

Armasight, Inc. is a U.S. Manufacturer, Supplier and Exporter of Night Vision and Thermal Imaging devices including monoculars, binoculars, goggles, clip-on, and weapons sighting systems that are designed for both military and civilian applications. The majority of our night vision devices utilize image intensifier tubes (IITs), while our thermal imaging devices utilize IRFPA based thermal imaging cores. All are sourced from vendors, because Armasight does not manufacture core technology IITs or IRFPAs.

Armasight has reviewed the proposed changes to Category XII and the EAR, and while we see some additional clarity regarding the "bright line" between ITAR and non-ITAR controlled commodities, there remains a lack of clarity in many areas. We address below portions of the proposed rules, providing our assessment and suggestions for your review and consideration.

- **The Definition of a Weapon Sight, versus an Imaging Device Should Be Clarified**
  - We feel that it would be helpful to clearly define what constitutes a "weapon sight," as this term remains undefined, but triggers controls. Over the last few years, Armasight has received conflicting rulings and opinions from DDTC and BIS as what defines a "weapon sight." Some rulings and opinions have indicated that, to be a "weapon sight", the article must have aiming capability (e.g., reticles), while others have indicated that the ability to place the sight on a weapon, regardless of aiming capability, is sufficient to make an item a "weapon sight". The conflicting views on this definition have led to our receiving unique and unusual rulings, such as a CJ that resulted in EAR jurisdiction, but indicated that the item is to be treated as a 6A992 imaging device if shipped alone, but as a 0A987 "weapon sight" if shipped together with an EAR99 universal weapon mount accessory. The particular item in question also lacks the ruggedness to survive weapon shock, but the mere theoretical ability to attach the imager to a weapon was cited as the basis for such a ruling. This ruling is inconsistent with the plain reading of the regulations and presents unique challenges in classifications of future products and maintenance of appropriate controls. Providing a clear definition in part 772.1 or in an explanatory note, outlining the

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specifications that would classify an article as a weapon sight, such as, “Unit must possess a fixed weapon mount, have an aiming reticle and user adjustable bore sighting capability, and be able to withstand weapons shock [at an appropriate performance parameter]” would eliminate some confusion within the industry and establish more consistent classifications for existent and future products.

- **GEN II Image Intensifier Tubes Should Not Be ITAR-Controlled**
  - Armasight sources all of its Generation II image intensification tubes from outside the United States, because there are no U.S. manufacturers of Gen II IITs. Foreign manufacturers include Photek, UK; DEP, Netherlands; Photonis, France; Harder Digital SOVA, Serbia; Bharat Electronics Ltd., India, along with 3-4 manufacturers in Russia and 2 in PRC. With no manufacturer of these commodities in the United States, the ITAR would be controlling foreign commodities brought into the United States that are distributed worldwide from the foreign manufacturers with little to no restrictions. Indeed, such controls serve more as an encouragement for U.S. companies to establish subsidiaries outside the United States to assemble and market such items, than they serve to protect the U.S. warfighter or preserve U.S. technological advantage.

  - We question Image Intensifier Tubes with luminous sensitivity exceeding 500 uA/lm being placed on the ITAR, as the photosensitivity of GEN II Image Intensifier Tubes at their highest level remains 3-4 times lower than the photosensitivity of the average GEN III Image Intensifier Tube. It is our opinion that GEN II IITs exceeding the 500 uA/lm threshold would be more appropriately placed in a 600 Series ECCN, or in 6A002, rather than on the ITAR, therefore placing the “bright line” at GEN III+ on the ITAR and GEN II and below as non-ITAR. We also think that 350 uA/lm is an outdated control on Gen II IITs, and the Wassenaar level should be raised to 500 uA/lm.

  - Additionally, we question the need for worldwide license requirements and elimination of license exception eligibility for GEN II IITs controlled by 6A002 (i.e., those with a luminous sensitivity exceeding 350uA/lm). Such controls would prevent Armasight from importing 6A002-equivalent IITs from suppliers in countries such as Ukraine, China or Serbia, into the United States for testing and quality control, then re-exporting them under STA to an assembler in an STA-eligible country. This reduces our flexibility in terms of where we can assemble our products where GEN II IITs can be exported from the foreign manufacturers in Serbia, China, Russia, etc. with little to no restriction.

- **IRFPA Based Weapon Imaging Systems Subject to the ITAR**

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- Armasight generally designs its IRFPA based Imaging Systems around third-party supplied IRFPA "Cores". The proposed ITAR control starts out by applying a bright line threshold of control over any Weapon Imaging Systems that incorporate an IRFPA with a peak response exceeding 1000 nm, which in turn could mean that Weapon Imaging Systems incorporating an EAR-controlled IRFPA would be controlled under the ITAR. We feel that this could lead to over control of, for example, weapons imaging systems incorporating 6A002 or 6A993 microbolometer IRFPAs that happen to have a peak response rate over 1000nm, but a frame rate at <9Hz. It does not make intuitive sense that the cores are subject to the EAR, but the end-item would be considered a defense article.

- The next control parameter includes the incorporation of any "article subject to this subchapter". This creates some interpretive difficulties, because the controls on bare IRFPAs, packaged IRFPAs, and cores incorporating packaged IRFPAs are not consistent. We assume that, if Armasight purchases a core from a vendor, we would only need to review the performance parameters of items controlled under XII(c)(12), and not "see through" to the controls applicable to IRFPAs called out in XI(c)(2) through (8). An explanatory note confirming that the "see-through" principle does not apply in these circumstances would be helpful. For example, there could be a note to XII(a)(2)(ii) that says "If the incorporated article is an IRFPA core, only the control parameters of XII(c)(12) are relevant to determination of ITAR control." Otherwise, it is possible that there could be confusion about whether incorporation into a Weapon Imaging Device of cores that are EAR controlled, but contain IRFPAs that would be controlled under the ITAR if not already incorporated into a core, would trigger ITAR control.

- There is further potential confusion and difficulty of drawing bright lines at the level of the Weapon Imaging System, because the controls on IRFPA cores set forth in XII(c)(12) include some items with FPAs that have a peak response below the 1000 nm threshold laid out in XII(a)(2)(i). For example. XII(c)(12)(i) includes certain shock-resistant cores with microbolometer IRFPAs exceeding 111,000 detector elements, but there is no specification of a peak response wavelength. XII(c)(12)(ii) covers a subset of microbolometer IRFPAs controlled under XII(c)(2) and (c)(5), which covers items that have a peak response rate between 900 nm and 30,000 nm, as well as having over 328,000 detector elements. Thus, there is a confusing interplay between the controls in XII(c)(i) and XII(c)(ii). On balance, while there is a hodgepodge of control parameters to consider, Armasight thinks it makes more sense to apply ITAR controls to IRFPA-Based Weapons Imaging Systems_only if they incorporate an ITAR-controlled IRFPA, or more realistically, an ITAR-controlled core as listed in (c)(12), and not to superimpose a control that would apply ITAR control to all

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Weapons Imaging Systems that incorporate an IRFPA with a peak response exceeding 1,000 nm, as that could impose ITAR control on Systems that incorporate EAR-controlled IRFPAs. If such EAR-controlled IRFPAs are not deemed sensitive enough to be subject to ITAR controls when exported by themselves, it doesn't make sense for Weapons Imaging Systems that incorporate them to be up-classified to the ITAR. We note that this would be consistent with the approach taken in Category XII(c)(13) for monoculars, binoculars, etc., although some of the interpretive difficulties mentioned above apply to the monoculars, etc., which generally incorporate vendor-supplied "cores", instead of integrating an IRFPA and custom read-out electronics.

- We do agree that applying ITAR controls to certain Weapon Imaging Systems that incorporate a ballistic computer for adjusting the aim point display is appropriate, but the way the control is written in Cat XII(a)(1)(iii) makes it unclear whether the control applies only to night vision capable Weapons Imaging Systems, or if it applies to daylight sights, which would fall under Category I. If the intent is to control only night vision devices in XII(a)(1)(iii), then an appropriate performance parameter or Note should be introduced, to avoid confusion about potential overlap with Category I items (either currently or after that Category goes through ECR).

- **EAR Controls on Weapon Imaging Systems Are Too Broad and Cover Items in Normal Commercial Use, the Order of Review Is Not Consistent with the Rest of the EAR, and Inconsistencies Between 0A987 and 600 Series Controls Lead to Unexpected Outcomes**
  - The EAR contains three potential ECCNs that could apply to non-ITAR night vision Weapon Imaging Systems: 0A987, 6A615.d, and 6A992. Based on the text of 6A615.d, which excludes items subject to 0A987, it appears that the order of review of these categories is first 0A987, then 6A615.d, then 6A992. This seems to diverge from the normal order of review laid out by BIS with respect to the CCL, as it is normally 600 series first, then all other ECCNs. An explanatory note in the Order of Review guidance may be helpful in avoiding confusion, because if one follows the normal order of review, 6A615.d would appear to cover all "weapon sights" operating between 700 nm and 1000nm but then the exporter is told that 6A615.d does not include items subject to 0A987, which could cause confusion about which ECCN to consider first.

  - We note, as an aside, that the lack of revisions to Category I still introduce confusion and lack of clarity between what is a "military" day sight and a non-"military" day sight subject to 0A987, and that the cross reference in Category I directing exporters to Category XII for controls on "night vision" military

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riflescopes would need to be more specific in terms of performance parameters (e.g., peak response wavelength or wavelength of operation) to be clear about which are Cat I and which are Cat XII. Adoption of a consistent terminology (e.g., "weapons sights") across the categories would also be helpful." While we understand that reforms to firearms categories are politically controversial, reform of the non-firearms portions of Category I regarding weapons sights seems necessary to resolve this confusion, and could be done as a partial reform of Category I.

- If a night vision Weapon Imaging System is not subject to 0A987, then the exporter is supposed to consider 6A615.d. However, 600 Series ECCNs are supposed to apply to items that are inherently military in nature, and 6A615.d imposes controls simply based on the wavelength of operation, which imposes 600 series controls on items, such as clip-on night vision systems, that are currently in normal commercial use, and many of which have been classified as 6A992 items by BIS in the past. Applying a 600 series ECCN to all clip-ons that operate in the range of 700-1000nm is an overly broad control. Only such items that are ruggedized, meeting higher military-grade standards for shock and containing higher-performing optical elements should be subject to 6A615.d, in keeping with the objectives of ECR not to impose controls on items in normal commercial use, unless they confer some differential military advantage or are produced predominantly in the United States.

- Another confusing aspect of these multiple ECCNs is that 6A615.d's description of controlled items includes, among other things, "Weapon Sights," but then excludes any items controlled by 0A987. 0A987 describes several types of "sights": "Telescopic sights," "Holographic sights," "Reflex or "red dot" sights," "Reticle sights," and "Other sighting devices that contain optical elements." This is a fairly broad description of the types of weapon sights, but it is not clear whether BIS and DDTC intend to cover all non-ITAR infrared weapon sights under 0A987, or if there may be some other types of sights that would be controlled by 6A615.d, but from Armasight's perspective, that seems like a null set of items. If so, it would be clearer to drop the description "weapon sights" from 6A615.d, and just make a cross reference in the Related Controls note to indicate that all non-ITAR "weapons sights" are controlled under 0A987. If, however, the US Government intends to control some infrared "weapon sights" under 6A615.d, then either 0A987 should be revised to be clearer about what types of infrared sights are to be controlled and which are not. It is very difficult for exporters to determine which types of "sights" are controlled under 0A987, due to the vague descriptions, which forces the submission of CCATS requests to determine what is the correct ECCN.

- If we are correct that 0A987 is intended to cover all non-ITAR infrared weapon sights, and other types of Weapon Imaging Systems operating in the

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wavelengths between 700 nm and 1000 nm are intended to be controlled under 6A615, there are some odd outcomes in terms of certain license requirements, since 0A987 controls do not overlap entirely with RS1 controls applicable to 6A615.d items.

0A987 was included in the EAR as a result of Firearms Convention and Crime Control requirements, and is subject to Crime Control, Firearms Convention, and United National Controls. While not expressly excluded from STA eligibility in 740.20(b)(2), like other 0A98X items, 0A987 is not, on its face, eligible for use of License Exception STA because, pursuant to 740.20(c)(1), it is subject to reasons for control other than NS, CB, NP, RS, CC or SI. 0A987 is subject to FC and UN controls, which go beyond what is listed in 740.20(c)(1) as being eligible for License Exception STA to A:5 countries.

That doesn't make a difference in most cases, because most A:5 countries are NLR destinations for 0A987 items. However, A:5 countries Argentina, Austria, Canada, Sweden and Switzerland require a license, and are not STA eligible. However, A:6 country Albania is an NLR destinations, while A:6 countries Hong Kong, India, Israel, Malta, Singapore, South Africa Taiwan require a license and are not STA eligible, because only NS-only items are eligible for STA to A:6 countries.

It would seem that night vision sighting devices would be perceived to be more sensitive than non-sighting Weapon Imaging Systems, but placing them in 6A615.d would apply a license requirement on a worldwide basis, although such items would be STA eligible for A:5 countries. Thus, 0A987 sighting devices can be shipped NLR to most A:5 countries and are eligible for APR, but less sensitive 6A615.d non-sighting devices would require additional STA assurances to go to the same countries and would not be eligible for APR. While not a major issue, it is also an odd outcome that 0A987 sighting devices would be able to go NLR to Albania, an A:6 country, but less sensitive non-sighting Weapons Imaging Devices, such as clip-ons, would require an individual license to Albania, because 600 series items are not eligible for STA to A:6 countries.

We recognize this complexity is due to the incomplete overlap between FC/CC/UN controls and NS/RS controls involving 600 series items, but these anomalies could be addressed by removing the license requirements for 6A615.d for 0A987 NLR countries, although STA eligibility should be retained for Argentina, Austria, Canada, Sweden and Switzerland for 6A615.d items, since non-sighting items are less sensitive and not subject to FC/CC/UN restrictions. We note that these additional controls would make more sense, and adjustments to the controls on 6A615.d would be less appropriate, if 6A615.d were to apply only to "military" grade night vision Weapon Imaging Systems, and not to civilian items, which would drop to 6A992 control.

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- **Creation of 0E987 Imposes Controls on Technology that Was Not Previously Controlled, Targets Technology that Is Widely Available Worldwide, and May Not Actually Control Any Technology at All, Because There is Very Little Technology Related to the Development or Production of Night Vision 0A987 Items that Is Not Identical to that Used to Develop or Produce non-Night Vision Weapons Sights.**
  - Technology for the development and production of 0A987 items is currently EAR99 controlled. The creation of a control for information related to the "production" or "development" of 0A987 sighting devices that contain infrared imagers imposes controls on technology that is not currently controlled, and which, to the extent it actually exists, is widely available on a worldwide basis.

    However, it is not likely that 0E987 actually controls much technology at all, as defined in EAR Part 772.1 and the General Technology Note. The General Technology Note and the definition of "required" limit controls on technology to that which is "peculiarly responsible" for conferring the specific characteristics or performance parameters that qualify an item for the ECCN in question. 0E987 would control technology that is "peculiarly responsible" for making a sight night vision capable vs. a day sight. Under the current and proposed re-definition of "peculiarly responsible", any technology that is the same for the development of an 0A987 day sight and a night vision 0A987 sight would not be "peculiarly responsible", and thus would not be controlled under 0E987.

    The technology to develop or produce the night vision element would already be controlled by 6E001 or 6E002, or by other category 6 technology ECCNs, so the difference between production or development of an 0A987 night vision versus an 0A987 day sight, generally speaking, would be what type of imaging device is dropped into the body of the sight. Adjustments to accommodate an infrared imager would likely be solely for "fit" purposes, or perhaps involve the substitution of infrared capable optics, which would likely be of standard sizes so they could "drop in" to an existing day sight design. Thus the scope of controls would likely be limited to fit modification information to allow integration of a night vision element into the body of a sight.

    To the extent controlled, such information would be widely available on a worldwide basis, as the minor changes to a design to permit interface with either a night vision or day optical element are well-known and available on a worldwide basis, as night vision weapons sights are produced in numerous countries. Thus, it would not appear that the creation of this ECCN would serve much purpose, other than to create uncertainty regarding whether export licenses may be required to assist with the design of weapons sights that is currently treated as EAR99.

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- Controls on Bodies and Kits Should Be Clarified, as Government Classifications Have Been Inconsistent
    - Armasight also believes that these changes should address more clearly the controls applicable to semi-knock-down kits for weapon sights and other night vision devices. U.S. government rulings have treated such parts and components – many of which are foreign manufactured plastic components – are ITAR controlled, and in some cases have treated them as EAR99. Introduction of a "specially designed" concept is helpful, but such items should perhaps be more clearly called out in a 6A615.y category – although that could even be an over control, since many such items are manufactured as COTS equipment in China. Overall, more rational treatment of such non-critical components would be welcome.

- **Foreign Availability of Identical and Similar Products**
    - It is important to note that the technology used to manufacture night vision and thermal imaging systems is available worldwide and there are many countries currently producing systems that are of equivalent to the U.S.-manufactured goods. In the competitive international market, we are regularly informed of foreign manufacturers that have the ability to provide higher grade systems to the end user, but with far less restrictions and that can be delivered within a shorter timeframe. It is becoming increasingly difficult for U.S. companies to compete in the international market as the buyers are quickly discovering that they can purchase articles with the same performance, and have it much sooner and without having to go through the additional processes required for U.S license applications.

    - While many of the restrictions in place are needed and justified, there are other restrictions on U.S goods that, to the competitive market, seem too stringent and have begun to push U.S companies out of the market in favor of the foreign manufacturers. This is making us non-competitive in many ways. We feel that an overall assessment of international availability and reasonable adjustments would be justified. It has become clear that foreign-manufactured items are meeting or exceeding the specifications of U.S. made goods, and U.S. companies will quickly be eliminated from competition in the international markets if we cannot offer high grade devices at fair prices without a substantial amount of wait time, paperwork and "red tape". If the regulations become too tight and the process becomes too complicated, the affected customers will buy from manufacturers outside of the United States which will provide those Foreign suppliers with the capital to improve their products through investment in R&D, improve their manufacturing capability along with other industrial infrastructure advancements that have multiple secondary and tertiary effects in the

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competitive manufacturing world. In addition, when a foreign customer is not buying from the USA, then we lose ground/naval/air order of battle intelligence which helps the US Armed Forces develop both tactical and strategic engagement planning. It does not appear that the proposed changes take these factors into account, given that they expand ITAR controls and remove License Exception eligibility from the EAR, further constraining an already stressed U.S. industry.

- **Overall Assessment of the Proposed Rules**
    - While there are some improvements made in the proposed rules, we feel there is still much to address to ensure that the rules are clear, concise and fair across the board. The language of the rules is still a bit confusing and allows for varied interpretations. This issue is one that has plagued many of companies in our industry, as some receive more favorable classifications than others for identical products, depending on the interpretation of the officials handling the case. Simplifying the regulations and creating more clarity will eliminate the inconsistent interpretations of the regulations and lead to a more equal and fair competitive market. In reading the proposed regulations, it is clear that a novice reader would have extreme difficulty interpreting these regulations and properly classifying products without having to file for CJs or CCATS.

    - It would make much more sense to focus ITAR controls on the limited number of IITs, IRFPAs, and thermal imaging cores that are truly at the top of the performance threshold, and which have primarily military applications. For example, it would be much clearer to simply control Gen II IITs as dual-use items, given that the U.S. military has left such technology behind and there is no U.S. manufacturer of such goods, reserving ITAR control for Gen III+ items. ITAR control should also be reserved for only high-performance, large format Vanadium Oxide/Silicon Microbolometer IRFPAs, as well as high-performance, large format compound semiconductor IRFPAs, recognizing that the parameters may differ based on detector composition. The attempt to differentiate controls based on whether or not the IRFPA is packaged is extremely difficult to comply with, and it would make more sense to impose tight controls on the manufacturing technology for IRFPAs, instead of trying to impose different license requirements on items at different stages of manufacture. The packaging differentiator also doesn't make much sense in light of the trend toward wafer-level packaging.

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If you have any questions regarding the comments herein, or require any additional information, please do not hesitate to contact me.

Sincerely,

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ASSOCIATION FOR UNMANNED VEHICLE SYSTEMS INTERNATIONAL

Submitted Via E-Mail (DDTCPublicComments@state.gov)

July 1, 2015

Mr. Edward Peartree
Director, Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
U.S. Department of State
Washington, DC

ATTN: Regulatory Change, USML Category XII

Re: Response to Request for Comments Regarding the Revision of USML Category XII

On May 5, 2015, the Directorate of Defense Trade Controls (DDTC) issued a Federal Register notice requesting comments on proposed revisions to Category XII of the U.S. Munitions List (USML) via amendments to the International Traffic in Arms Regulations (ITAR).[1]

The Association for Unmanned Vehicle Systems International (AUVSI), the world's largest non-profit organization devoted exclusively to advancing the unmanned systems and robotics community, respectfully submits these comments on behalf of more than 7,500 members.[2]

AUVSI supports the effort to exclude light detection and ranging (LIDAR), laser detection and ranging (LADAR), and range-gated systems or equipment that are or will be used in civil automotive applications from control under the ITAR. These systems can provide key safety features for automobiles with autonomous and driver-assist functionality that will contribute to public safety. AUVSI's members are concerned, however, that the proposed language in USML Category XII(b)(6) and the accompanying note will create confusion for the industry, as described below. AUVSI also respectfully recommends that any exemption be expanded to include **civil vehicle applications**, not just civil automotive applications.

[1] Proposed Rule, Amendments to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, 80 Fed. Reg. 25821(May 5, 2015).

[2] AUVSI is committed to fostering, developing, and promoting unmanned systems and robotic technologies. More information about AUVSI can be found on our website, at AUVSI.org.

1. The proposed language in the note to (b)(6) creates confusion

The note to (b)(6) is based on intended end use, not on objective criteria. The proposed language excludes equipment "for civil automotive applications" from ITAR control if it fits within the specified range limitation. This language potentially creates a different level of control for the same item, depending on its intended use. For example, a LIDAR system intended for sale to an automobile company for use in commercial vehicles would be released from control under (b)(6) (and may therefore be subject to the EAR). However, the exact same LIDAR system, if sold to a non-automotive company, would remain subject to the ITAR. Such a rule would create confusion for companies manufacturing, selling, and receiving those systems and related technical data. The lack of objective criteria also does not support the goal of Export Control Reform to "create a 'positive list' that describes controlled items using, to the extent possible, objective criteria rather than broad, open-ended, subjective, or design intent-based criteria."[3]

2. Potential over-control of LIDAR for use in other civil vehicles

The proposed control language in (b)(6) potentially captures LIDAR and related systems that are or are expected to be used by other civil vehicles, including certain commercial / civil unmanned aerial vehicles (UAVs). As in civil automotive applications, civil UAVs use LIDAR and related systems to avoid collisions. The use of these systems is expected to be critical in ensuring the safe use of civil UAVs as they are integrated into the national airspace. Thus, inclusion of such systems on the ITAR could seriously hinder the development and deployment of LIDAR and related systems in civil UAVs, to the potential detriment of public and air safety and the growing civil UAV industry.

AUVSI therefore respectfully requests that DDTC revise the note to (b)(6) to ensure that a broader category of "**civil vehicle applications**" are excluded from control under (b)(6). Such a revision would help to ensure that the reform of Category XII's does not retard the development of critical LIDAR and related safety systems for civil unmanned vehicles (and manned vehicles with autonomous and pilot-assist systems). AUVSI further requests that the current proposed 200 m range limitation in the note to (b)(6) be **expanded to 1,500 m** to accommodate LIDAR and related systems that are deployed for collision avoidance and other safety applications in civil UAVs. UAVs that are capable of moderate speeds need systems with range capabilities of at least that amount to provide sufficient time for the UAV's autonomous systems to sense and avoid objects in their flight path. Of course, some smaller UAVs with more limited speed capabilities can safely employee LIDAR and related systems with ranges of 200 m or less for collision avoidance purposes, however many systems should have access to the longer range specified above to promote safety.

Again, AUVSI prefers that the ITAR use a "positive list" format to control LIDAR and related systems, excluding from control systems that are or are expected to be used in civil vehicle applications – automotive and aerial. To the extent such a revision is not possible, AUVSI requests that the note to (b)(6) be expanded to exempt systems used in civil vehicle applications with a range of up to 1,500 m.

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[3] Final Rule, Amendment to the International Traffic in Arms Regulations; Initial Implementation of Export Control Reform, 78 Fed. Reg. 22740 (Oct. 15, 2013).

*　　*　　*

Please contact the undersigned at (571) 255-7786 or tmcmahon@auvsi.org with any questions or for additional information.

Sincerely,

Tom McMahon

Tom McMahon
Vice President,
Advocacy & Public Affairs
Association for Unmanned Vehicle
Systems International

July 6, 2015

Office of Defense Trade Controls Policy
Department of State
Washington, DC
By email to DDTCPublicComments@state.gov

RE: ITAR Amendment—Category XII

Dear Sirs/Madams,

I am writing on behalf of the Association of University Export Control Officers (AUECO), an association of over 115 senior export practitioners with export compliance responsibilities at more than 90 accredited institutions of higher education in the United States. As expressed in its founding charter, AUECO is committed to monitoring changes in the administration of export laws and regulations that could affect transactions and collaborations in academia.

AUECO is providing the following comments in response to the Department of State Proposed Rule for *Amendment to the International Traffic in Arms Regulations: Revision to U.S. Munitions List Category XII* (RIN 1400-AD32). AUECO is specifically interested in contributing to the export reform effort in order to ensure that the resulting regulations do not have an adverse impact on academic pursuits, and offer the following comments.

As export officers at universities conducting academic research, we are keenly aware of the value of some of the technologies described in the proposed Category XII as having dual uses in areas such as astronomy and space science, oceanography, telecommunication, photonics, computer processor-memory interconnects, materials engineering, thermal management, energy storage, energy conversion, photovoltaic devices, groundwater management, computational ophthalmology, and molecular medical diagnostic tools. There should be a clear delineation between items that have military and non-military end uses.

Request for note to be added to Category XII

We would recommend that Category XII include the following clarification note:
"Category XII does not apply to items that are specifically made for non-military end uses, such as astronomy, including stationary ground-based systems and telescope instruments, meteorology, other research or commercial end uses."

Comments on ITAR XII (b)(2)

There are commercial products (e.g., laser trackers) which meet this definition and cannot be converted to defense use. We recommend that the technical parameters be changed to exclude commercially available items.

Comments on ITAR XII (b)(3)(i)(ii)

There are commercially available products (e.g., FLIR, a commercial company) that would now be ITAR-controlled under this definition. We recommend that the technical parameters be changed to exclude commercially available items.

Comments on ITAR XII (b)(6)-(8)

XII(b)(6)-(8) – LiDAR systems can be used for meteorological purposes. It is possible that meteorological systems can be built to the specifications described in paragraphs (7)-(8).

Request for note to be added to Category XII (b) (6)-(8)
A note should be added that paragraphs (6)-(8) do not control LiDARs or other laser range-gated systems or equipment built for meteorological purposes or already commercially available.

Comments on ITAR (b)(11) and (b)(12)
Increasing the power from 1W to 2W is helpful.

Comments on ITAR (b)(13)
A power density of xxW/cm2 is stated, and power density depends on how the laser is focused using lenses external to the laser itself. This will be confusing because it is mostly an issue of how the user will use the laser, and we typically assume the laser is focusable.

Request for Wording Changes to ITAR XII (b)(13)

- We suggest the power density be changed to power (in terms of Watts) and also point to the focusability of the laser.
- Item (b)(13)(iv) should be deleted because companies such as IPG Photonics already sell commercial lasers at that wavelength with 100 times more power, in the several kW range.

Comments on ITAR XII (b)(14)
This sub paragraph is an overly broad statement of control that implies the funding source (Department of Defense) of lasers or laser systems will dictate whether or not the systems should be controlled as a munition. Per Note 1 to paragraph (b)(14), if a contract fails to include language that the system or equipment being developed is for both civil and military applications, then the system or equipment would therefore be ITAR-controlled.

Much initial work on lasers and laser systems is based on public domain information, conducted by universities, and may be sponsored under Department of Defense 6.1 (basic research) or 6.2 (applied research), which in most cases would be considered fundamental research under the ITAR.

Request for Wording Changes to ITAR XII (b)(14)
The proposed wording of this sub paragraph if not clarified will negatively impact research conducted at universities. Lasers not meeting the requirements for a military end use should not be controlled under ITAR, even if their development was funded by the Department of Defense.

Under the proposed definition of "development" (80FR 31525), it states "all stages prior to serial production, such as: design….", which could be thought to include any basic or applied research which is used in the design. This is clearly counter to the definition of fundamental research. The definition should include a statement that development does not include that work which would be considered fundamental research.

Comments on ITAR XII (c)
XII(c)(2)-(12) – Infrared focal plane arrays (IRFPA) may be used in astronomy in the development/production of land-based telescopes. These telescopes have a scientific purpose and do not have a military end use. Astrophysical investigations have expanded, along with technology, to encompass nearly all wavelengths. The infrared bands, which appear to be the subject of the new regulations, are especially important with their ability to see things otherwise blocked in the optical by gas and dust in the interstellar medium. These proposed regulations will affect infrared and sub-millimeter instrumentation.

Some techniques and hardware used in infrared instruments will be proposed for use at other wavelengths, including the X-ray band. The same bolometers used in the infrared have been adapted to be used in the X-ray band, for instance. State of the art infrared detectors for instruments that may be proposed/flown on scientific satellites and may be and are used in ground-based telescopes outside of the U.S. may be impacted by the proposed export regulations. MilliKelvin bolometers are also used in the X-ray wavelength bands, as they are used in the infrared. This would also affect them. Many of the best ground based astronomical sites are not in the United States, but in Chile, the Canary Islands, South Africa and other foreign destinations. Additionally there are multi-national teams participating in this research with these instruments and ITAR jurisdiction of this items could exclude participation of certain nationals.

Comments on ITAR XII Note 1 to paragraph (c):
The intent of this Note is unclear and should be clarified as to its applicability.

Comments on ITAR XII Note 2 to paragraph (c)(2): 12 (iii)
Some of these requirements are causing undo competitive advantage for foreign companies. For example, the proposed requirements will give Sofradir, a French company that produces bolometers and photon detectors, an advantage over U.S. Companies.

Request for Defined Terms ITAR XII(c)(2), (c)(4) and (c)(12)
We would recommend the following terms be defined:

- XII(c)(2) – "Integrated"
- XII(c)(4) – "Permanent encapsulated sensor assembly"
- XII(c)(12) – "Infrared imaging camera core"

Comments on ITAR XII (c)(7)
Current commercial applications of charged multiplication FPAs are now at 1,000 elements, but it is believed the commercial world will surpass 1,600 elements in the near future. Currently, there are leading foreign suppliers, such as Andor, with headquarters in the UK and locations in China, Japan and the U.S. of electron multiplying charge coupled devices for scientific, non-military-related research. Current applications for these cameras are for smaller devices but larger devices will soon be available from such foreign suppliers (e.g. greater than 1,600 elements in any dimension and having a maximum radiant sensitivity; exceeding 50mA/W for any wavelength exceeding 760 nm but not exceeding 900nm and avalanche detector elements).

Comments on ITAR XII(c)(9)
Even though the IRFPA (used in a land-based telescope) may have been developed for spaceflight or military use, we consider XII(c)(9) as overly broad when applied to commercial dewars, cooling systems and electronics that were not specifically designed to be used with controlled IRFPAs. Nor do we see a value in controlling the integrated dewar cooler assemblies which are custom-made for astronomical purposes. Under the proposed XII(c)(9), dewars, cooling systems, electronics and optics that were designed for commercial purposes would be controlled under the ITAR solely because of their use with a controlled IRFPA. Integrated IRFPA dewar cooler assemblies (IDCAs), with or without IRFPAs, can be put together easily by anyone who purchases a cooler from commercial suppliers such as Air Liquide, and a commercially available infrared detector array can be currently purchased from a U.S. company.

Examples of commercial cryocoolers using fully encapsulated detector array systems could include Pulse-tube cryocoolers, Gifford-McMahon cryocoolers, sorption refrigerators, adiabatic demagnetization refrigerators, and dilution refrigerators (not an exhaustive list), all of which are used for cooling astronomical focal planes and which are well-described in literature in the public domain. Examples of ECCN designations for commercial equivalent products captured by the revised ITAR XII include:

- Cryomech, Inc. - Gifford-McMahon Cryorefrigerators are EAR99 for part numbers: AL10, AL25, AL60, AL63, AL125, AL200, AL230, AL300, AL325, AL330, AL600.

- SHI Crygenics - Pulse Tube Cryocooler Series are EAR99 for part numbers: RP-062B 4K Pulse and RP-082B2 Pulse.

These commercially available devices could be purchased and used for other purposes without being subject to the ITAR, but once the products are associated with a controlled IRFPA, the devices would need to be controlled. This leads to a confusing and poorly manageable situation for a scientific or research organization.

Because these components would be subject to ITAR restrictions, details of their design or integration into the IRFPA system could not be discussed in scientific publications. However, because these are commercial products, it is very possible that details of their design and use are already in the public domain.

Request for Defined Terms ITAR XII(c)(9)
We request a better definition of what is included in an integrated IRFPA dewar cooler assembly. For example, are the following items to be included?

1. Optics within the dewar.
2. Cooling system components installed outside of the dewar, in some instances mounted at a distance from the dewar or part of a telescope facility and not directly part of the instrument.
3. Electronic control systems for the cooling system, which again may be mounted away from the dewar.
4. Systems used to control heating of the dewar (separate from the cooling system).
5. Optics mounted outside of the dewar that interface with the optics within the dewar.

Request for Wording Changes to ITAR XII (c)(9)
We recommend that integrated IRFPA dewar cooler assemblies (XII(c)(9)) be removed from ITAR control or reworded to remove ITAR controls on commercial or custom components made for non-military, scientific purposes.

Comments on ITAR XII (c)(17)
While certain telescopes do not meet this description the components could be rearranged to meet or exceed these technical parameters. Six meter telescopes may likely exceed these technical parameters. We recommend that the technical parameters be increased. We recommend that the mirror size be changed to be greater than 8.4m to recognize the existence and operation of presently operating observatories such as Keck and the Large Binocular Telescope.

Comments on ITAR XII(e)
This section has similar concerns to XII(c)(9) and is overly broad in its controls. It does not specifically state what technologies need to be controlled or specify the end uses of that technology.

XII(e)(7)(i) - Stirling cryocoolers are based upon technology that was conceived in the 1800s, have been produced since the mid-1900s and are well-described in the public domain. Protecting this technology would not appear to improve national security.

Request for Wording Changes to ITAR XII (e)(7)(i)
Stirling cryocoolers should be exempted even though they may meet the specifications as described in this section.

Comments on ITAR XII(e)(7)(iv)
Dewars that are specially designed for IRFPAs for non-military purposes (astronomy) impart little, if any, information regarding the technology of the IRFPA that is not already described in the literature (for the particular IRFPA being used). Controlling the dewar because of its use with a controlled IRFPA can provide similar concerns as described in Comments on ITAR XII(e)(9) below.

Comments on ITAR XII(e)(9)

This section should consider the application of the parts and components. A land-based astronomical telescope that contains an IRFPA would likely include numerous optical elements including lenses, beam splitters, mirrors, filters, gratings and etalons, many of which could be treated or coated in specific manners.

It can be difficult to find a company to make custom optical elements for such a scientific device when considering process capabilities (of the company to make a specific element), quality considerations, overall cost and delivery schedules. In some instances, the best candidate may be a foreign vendor. An export license would be required to export the design specification as technical data for the manufacture of these components and would increase Agency and project workload, solely because these elements are to be used with an IRFPA.

Also, domestic vendors that produce such optical elements may need to review their staffing to determine whether a license is required for any foreign persons working within their facility. Alternatively, they may decide that they will not supply optics for equipment that contains ITAR components due to the overhead costs in supporting that activity. Any of these scenarios could compromise a research organization's ability to procure or create high quality optical elements. This issue also would increase the regulatory burden on the research project, vendor and Agency with no likely national security impact.

XII(e)(9) – This paragraph is overly broad in that it can include optical elements that are not enclosed or attached to the IRFPA dewar cooler assembly. This could be read to include all optical elements within the beam path of a scientific instrument.

In some cases foreign graduate students may be developing these custom optical elements as part of their studies and are actively participating in the manufacture of these items in machine shops at universities all under the auspices of fundamental research.

XII(e)(10) – The signal or image processing electronics may require custom electronics and software to produce a scientifically usable image when used with an IRFPA in an astronomical telescope. The application of the IRFPA should be considered when reviewing what is controlled. Uses that are not considered military should not be controlled under the ITAR, particularly for parts and components used in association with a controlled IRFPA.

If we look collectively at sections XII(c)(2)-(9), XII(e)(7) and XII(e)(10) and consider their application to a land-based astronomical telescope using a controlled IRFPA, the entire functional portion of the telescope would be controlled regardless of whether the assemblies, parts and components were custom or commercial items, merely because they are used with an IRFPA. The list of items that would need to be controlled include mirrors, lenses, beam splitters, coatings/treatments on optics, filters, gratings, etalons, dewars, cooling systems for dewars, controllers for the cooling systems, imaging electronics, image processing hardware and software, and any electronics interfacing with the IRFPA.

In a telescope, this may require the control of tens to hundreds of parts, which would be a severe hardship on a research institution or university. Vendor control would be extremely hard to manage and may result in some vendors not wanting to manufacture parts (for such ITAR controlled projects), thereby limiting the research institution's ability to source quality parts and components.

We consider the control of all of these components because of their association with an IRFPA to be a severe overreach that provides no particular additional security regarding the technology the government wishes to control, namely the IRFPA.

Since the entire imaging chain of the telescope would be controlled, publication of the design of the telescope would not be possible, thereby preventing researchers from advancing the design knowledge in their field (it would be a defacto publication restriction). Secondly, it may prevent universities or research institutions from taking on such a project due to the potentially extreme regulatory burdens of the project. In many instances, research instrumentation is developed by consortiums of domestic and foreign collaborators. The sort of regulatory controls described in the proposed regulations could lead to a substantial increase in licensing due to foreign collaborations.

This overreach on systems containing IRFPAs and associated parts and components is similar to Category XV for space technology prior to export control reform. If entire space systems, parts and components were moved from the USML to the CCL, why is the U.S. government putting commercial and research items by association with IRFPAs under munitions controls?

Request for definition on ITAR XII(e)(13)

Resonator needs to be defined. It is unclear if this is for a resonator for gain.

Request for Wording Changes to ITAR XII (c), (e) and (f)

An exemption to sections XII(c) and XII(e) should be made for assemblies, parts and components that are used in conjunction with an IRFPA for land-based astronomical and other non-military uses.

XII(f) – Technical data associated with assemblies, parts and components used in conjunction with a IRFPA for land-based astronomical telescopes and other non-military uses should be exempted from these requirements as described in section XII(c) and XII(e) above.

AUECO appreciates the opportunity to provide the Department of State with the above comments on ITAR Amendment—Category XII to enable the government to understand how the technologies we are developing and using are being impacted by export controls. The research enterprise in the United States is critical to the economic advancement of our country and having export regulations that are not overly broad ensure that innovation is not stifled in performing fundamental research.

Sincerely,

Mary Beran

Chair
Association of University Export Control Officers
Website: http://aueco.org

AUTO ALLIANCE

DRIVING INNOVATION®

July 6, 2015

By Email (DDTCPublicComments@state.gov)

Ms. Rose E. Gottemoeller
Under Secretary, Arms Control and International Security
U.S. Department of State
Washington, DC 20522

Re: ITAR Amendment – Category XII

Dear Secretary Gottemoeller:

The Alliance of Automobile Manufacturers, or Auto Alliance ("Alliance"), appreciates the opportunity to comment on the proposed rule amending Category XII of the U.S. Munitions List, as published by the Directorate of Defense Trade Controls ("DDTC") on May 5, 2015. 80 Fed. Reg. 25821 (2015). In its proposed form, the amendment would impair important safety-related research and development by the civil automotive industry. These comments suggest revisions to the proposed rule to ensure that it meets its intended exemption of civil automotive applications.[1]

The Alliance is an association of 12 vehicle manufacturers, including BMW Group, Fiat Chrysler Automobile US, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, Volkswagen Group of America, and Volvo Cars North America. The Alliance is America's leading advocacy group for the automotive industry; its members account for 77 percent of all car and light truck sales in the United States. The Alliance is committed to developing and implementing constructive solutions to public policy challenges that promote sustainable mobility and benefit society in the areas of the environment, energy, and motor vehicle safety.

Light detection and ranging ("LIDAR") systems are one of the most promising technologies for obstacle detection and avoidance and the reduction of rear-end and head-on auto accidents. The National Highway Traffic Safety Administration estimates that rear-end collisions each year result in over $15 billion in U.S. economic losses. U.S. Department of Transportation, "Connected Vehicle Insights: Trends in Roadway Domain Active Sensing," FHWA-JPO-13-086, at 1 (August 14, 2013) ("DOT Report"). These estimated losses would be even greater if head-on collisions were included. Furthermore, the U.S. Department of Transportation estimates that human errors are the cause of more than 75 percent of all auto accidents. DOT Report at 10. Automotive LIDAR systems (particularly in higher automation applications, SAE J3016 Level 3

[1] One or more Alliance members may submit their own comments independently of these.

and above) have the potential to mitigate, or even eliminate, the human error factor that could result in rear-end or head-on auto accidents. These systems could enhance substantially the safety of such common driving situations as merging into high-speed highway traffic or approaching from the rear a broken-down vehicle in a highway lane or using as a passing lane a lane used by oncoming traffic.

We note that the proposed rule seeks to exempt from the scope of Category XII those LIDAR systems for civil automotive applications. 80 Fed. Reg. at 25825 (referring to LIDAR in paragraph (b)(6) of proposed Category XII but adding in a note: "This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less."). But there are several aspects of the exemption as proposed that would actually constrain the development of LIDAR systems for civil automotive applications.

First, the proposed range limitation of 200 meters is too restrictive. Automotive LIDAR systems with a range in excess of 200 meters are already in the development stage. The longer range is necessary for object detection that achieves safety in the kinds of situations described above. Vehicle braking distance depends on a number of variables, such as mass of the vehicle, quality of the tires, character of the road (surface conditions, grade, curvature), weather, and others. A typical passenger vehicle traveling at 60 miles per hour has a braking distance of around 143 meters in ideal conditions, but that braking distance exceeds 400 meters in worse conditions. See http://blog.esurance.com/stopping-distance-is-the-3-second-rule-wrong/#.VZF9g_lVhBc (distances in feet are converted to meters at the conversion rate of 3.28 feet per meter). Notably, vehicle speeds on most major highways often exceed 60 miles per hour, due to higher posted speeds and to actual speeds in excess of the posted speeds. Furthermore, if vehicles are approaching each other, as could be the case where a vehicle is using an oncoming traffic lane as a passing lane, the convergence could be much faster than 60 miles per hour, and it would be imperative to begin stopping at a correspondingly longer distance. Finally, since a vehicle's acceleration capability is typically less than its deceleration capability, acceleration-based maneuvers, such as merging into moving traffic or crossing a road with high-speed traffic, require even greater distance-of-view than does deceleration. For these reasons, we recommend that the civil automotive exemption should use a range of at least 400 meters.

Second, the proposed range limitation does not distinguish between reflective and non-reflective objects. The detection range of a LIDAR system varies depending on the reflectivity of the object in view. A LIDAR system can perceive a reflective traffic sign, for example, at a much longer distance than a downed tree or a pedestrian. Therefore, we recommend that the civil automotive exemption should specify that the range relates to non-reflective objects, since a range that relates to reflective objects would leave the exempt range for pedestrians much shorter.

Third, the proposed exemption for LIDAR with civil automotive applications is undermined by the proposed controls on critical components of LIDAR systems. Automotive LIDAR systems often incorporate Geiger-mode detector arrays (proposed to be controlled by Category

XII(b)(8)(iii)); infrared focal plane arrays ("IRFPAs") (proposed to be controlled by Category XII(c)(2), (3), (4), and (6)); infrared imaging camera cores (proposed to be controlled by Category XII(c)(12)); and readout integrated circuits ("ROICs") (proposed to be controlled by Category XII(e)(4) and (5)). For example, in order for an automotive LIDAR system to be capable of determining the size, shape, direction, and velocity of an object while the LIDAR-equipped vehicle is moving, the LIDAR system must incorporate an IRFPA. Since an item containing an ITAR-controlled component is subject to ITAR control itself, automotive LIDAR systems containing an IRFPA or any other of the above controlled components could be considered subject to ITAR controls despite the civil automotive exemption.

To avoid any confusion on this score, we recommend that the exemption in Note 1 to paragraph (b)(6) expressly include components of LIDAR systems with civil automotive applications. We also recommend that the Note to paragraphs (b)(4) and (b)(6) through (8) be revised to exempt Geiger-mode detector arrays incorporated into civil automotive LIDAR systems, that Note 1 to paragraph (c)(2) be revised to exempt IRFPAs incorporated into civil automotive LIDAR systems, that paragraph (c)(12)(viii) be revised to increase the resolution standard to 327,680 detector elements (the standard video graphics array is already 307,200 pixels, and 327,680 is the next higher resolution), and that the Note to paragraph (e) be revised to exempt ROICs incorporated into civil automotive LIDAR systems.

We note that the technology that we are recommending be expressly included in the civil automotive exemption is widely available abroad. For example, Chunghwa Leading Photonics Tech, a division of Chungwha Telecom Co., Ltd. in Taiwan, Cox Co., Ltd. in Korea, and Xenics NV in Belgium offer IRFPAs with wavelengths in the range of 800-1700 nm. More generally, automotive LIDAR systems are being developed in China, Germany, and Japan, among other countries.

For the foregoing reasons, we recommend that the proposed rule be revised, in relevant part, as follows:

(1) Note 1 to paragraph (b)(6) should read as follows: *"Notwithstanding any other provisions of this category, ITAR does not control LIDAR systems and equipment, nor parts or components of such systems and equipment, for civil automotive applications having a range limited to 400 m or less for non-reflective objects."*[2]

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[2] The proposed paragraph (b)(6) controls both LIDAR and LADAR systems, but the proposed civil automotive exemption mentions only LIDAR systems. Since LIDAR and LADAR are essentially interchangeable technologies, we recommend that DDTC add a reference to LADAR in Note 1 to paragraph (b)(6) as well as in related civil automotive exemptions recommended in these comments.

(2) Note to paragraphs (b)(4) and (b)(6) through (8) should include a concluding sentence as follows: *"Geiger-mode detector arrays described in paragraph (b)(8) and incorporated into civil automotive LIDAR systems are exempt pursuant to Note 1 to paragraph (b)(6)."*

(3) Note 1 to paragraph (c)(2) should include a concluding sentence as follows: *"IRFPAs described in paragraph (c) and incorporated into civil automotive LIDAR systems are exempt pursuant to Note 1 to paragraph (b)(6)."*[3]

(4) Paragraph (c)(12)(viii) should read as follows: *"A two-dimensional photon detector IRFPA described in paragraph(c)(2) or (4) of this category having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm, and greater than 327,680 detector elements."*

(5) Note to paragraph (e) should include a concluding sentence as follows: *"ROICs described in this paragraph and incorporated into civil automotive LIDAR systems are exempt pursuant to Note 1 to paragraph (b)(6)."*

The foregoing revisions would ensure that the ITAR does not impair research and development that, while not advancing any military applications, could have significant benefits for civil automotive safety.

We appreciate the opportunity to submit these comments and would be pleased to answer any questions that DDTC may have with regard to our recommendations.

Sincerely yours,

Will Otero
Director, Transportation and Safety Policy

[3] Pursuant to this recommendation, we urge DDTC to communicate with the Bureau of Industry and Security to delete the proposed comment in Note 3 to Export Control Classification Number 6A002.a.3 that focal plane arrays that are not in a permanent encapsulated sensor assembly "are subject to the ITAR." 80 Fed. Reg. 25798, 25812 (2015).

Autoliv

July 2, 2015

Directorate of Defense Trade Controls
U.S. Department of State
c/o DDTCPublicComments@state.gov

Subject: ITAR Amendment – Category XII

Bureau of Industry and Security
U.S. Department of Commerce
c/o publiccomments@bis.doc.gov

Subject: RIN 0694-AF75

Ladies and Gentlemen:

On behalf of Autoliv ASP, Inc., the U.S. subsidiary of Autoliv, Inc. ("Autoliv"), I am sending this letter as our public comments to your proposed revisions to the Export Administration Regulations ("EAR") and International Traffic in Arms Regulations ("ITAR"), requested in your May 5, 2015 Federal Register notices.

I. Autoliv's Safety Products for the Civil Automotive Industry

Autoliv is the worldwide leader in civil automotive safety systems, and develops and manufactures civil automotive safety systems for all major civil automotive manufacturers in the world, including airbags, seatbelt devices, night vision, and other passive and active safety systems. Together with its joint ventures, Autoliv has more than 80 facilities with more than 60,000 employees in 28 countries. In addition, the Company has ten technical centers in nine countries around the world, with 21 test tracks, more than any other automotive safety supplier. Sales in 2014 amounted to US $9.2 billion. Autoliv estimates that its civil automotive safety products save over 30,000 lives every year, and prevent 10 times as many severe injuries. Autoliv's electronics facility in Goleta, California, designs, develops, and produces civil automotive night vision systems that likewise save lives across the globe. The use of infrared cameras in the civil automotive market has grown throughout the past 10 years. From the first systems which provided an image to drivers allowing them to see 3 to 5 times farther than their headlamps, to the current systems providing the driver with warning of pedestrians and animals in the path of vehicle, Autoliv's night vision cameras have made civil automobiles safer.

There are over 100,000 pedestrian fatalities and more than 1.5 million car-deer accidents globally each year. Nearly 70 percent of these fatalities happen at night. Our night vision camera systems are instrumental in reducing accidents and saving lives of pedestrians, vehicle occupants and animals.

The use of our infrared cameras in civilian passenger land vehicles continues to grow as the civil automotive market continues its path to providing safer vehicles. The U.S. Tech Choice Study published by JD Power in April 2015 identified night vision as the second most preferred civil automotive technology (behind only "blind spot detection and prevention"). MarketsandMarkets recently reported that by 2019 the automotive night vision system market will reach $2.5 billion and the automotive driver monitoring system market will reach $4.9 billion. Infrared cameras will also assist in achieving autonomous driving vehicles in the future.

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II. General Comments Regarding Proposed Rules

Because of this increased usage of infrared sensors and cameras to improve safety and save lives in the civil automotive market, we respectfully request that both the Department of State and the Department of Commerce consider relaxing the current export requirements for civil automotive infrared components, technology, software, and systems. The proposed rules, in contrast, appear to impose additional constraints and complexity that we believe are not necessary, particularly in light of the current, effective EAR and ITAR controls on related hardware, software and technology.

Our civil automotive OEM customers have successfully committed themselves to compliance with the existing export control regulations, and they also have found the proposed rules to be both confusing and more restrictive. Some already have suggested looking outside the United States to meet their future infrared sensor and camera needs for civilian passenger land vehicles in order to avoid the confusing and restrictive language being proposed. There are currently sensor and camera manufacturers delivering these civil products without such restrictions in France (please see: www.ulis-ir.com), China (please see: www.dali-tech.us , http://www.militram.com/category/articles/cameras-articles/beam-profilers-cameras/thermal/uncooled/ , http://www.suncti.com/en/index.aspx) and Japan (please see: http://www.solteccorp.com/).

III. Specific Comments Regarding Proposed Rules

Autoliv makes infrared cameras specially designed for installation in civilian passenger land vehicles, and those cameras are classified in the Commerce Control List ("CCL") under ECCN 6A993.a. because our cameras meet the criteria of Note 3 to ECCN 6A003.b.4. and related Wassenaar Arrangement provisions, including an anti-tamper mechanism. Our cameras include infrared focal plane arrays (IRFPA's) that, if exported separately, are controlled under the current U.S. Munitions List ("USML") Category XII(c), but are subject to EAR controls when exported as part of our civil automotive cameras, in accordance with the current USML Category XII(c). These ITAR and EAR provisions have worked well to ensure export compliance, in addition to providing a "bright line" between the USML and the CCL for the control of our products.

In contrast to the current regulations, the proposed USML Category XII(c) items related to Autoliv's civil automotive products, and the related proposed Note 2 to paragraph (c) and proposed Note to paragraph (e) appear to us to be confusing. Under the proposed USML Category XII(c) provisions, our civil automotive cameras would include IRFPA's that are incorporated into permanent encapsulated sensor assemblies (including a "vacuum package") that are incorporated into camera cores that are incorporated into our ECCN 6A993.a. cameras, which include also infrared lenses and processing electronics.

Under the proposed rules, the IRFPA's would be controlled under Category XII(c)(2), but once integrated into a permanent encapsulated sensor assembly, they would be controlled under Category XII(c)(4), having greater than 256 detector elements. The camera core into which the Category XII(c)(4) IRFPA is incorporated would be classified under Category XII(c)(12)(ix). Once our microbolometer IRFPA has greater than 328,000 detector elements and is in a permanent encapsulated sensor assembly, it would be controlled under Category XII(c)(5). The camera core into which the Category XII(c)(5) IRFPA is incorporated would be classified under Category XII(c)(12)(iii). Once the vacuum packages under Category XII(c)(4) and Category XII(c)(5) are incorporated into a camera core, it appears that they also would be classified under Category XII(e)(6). The infrared lenses would be classified under Category XII(e)(9), and the processing electronics would be classified under Category XII(e)(10). We found these multiple alternative classifications to be confusing.

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In addition, in order for our civil automotive camera, which includes a camera core, permanent encapsulated sensor assembly, IRFPA, infrared lens, and processing electronics, to meet the requirements for EAR control under the proposed Category XII Note 2 to paragraph (c) and Note to paragraph (e), the "article" "cannot be removed without destruction or damage to the article or render the item inoperable." It is unclear whether the "article" or the "item" is the camera, the camera core, the permanent encapsulated sensor assembly, the IRFPA, the infrared lens, or the processing electronics. It also is unclear how the two Notes would or would not permit the export of our currently ECCN 6A993.a cameras for installation in civilian passenger land vehicles. All of these "articles" or "items," other than the IRFPA's, can be removed without damage or destruction. If our civil automotive camera is disassembled, all of these "articles" or "items" would become inoperable in the sense that they only work together as a civil automotive camera, but each component remains operable in the sense that it could be used subsequently in an assembled system. In general, all components making up our ECCN 6A993.a. cameras that meet the requirements for civilian passenger land vehicles under Note 3 to ECCN 6A003.b.4., including the anti-tamper mechanism, should remain under EAR control, rather than ITAR control.

Regarding the wording on shock requirements at proposed Category XII(c)(12)(ii), the civil automotive market has high quality requirements to prevent such defects that may cause harm to the driver, occupants or pedestrians. The automotive shock requirements vary by OEM but are approximately 100g, 11ms, half sine, and we do not measure beyond these requirements. It is unclear whether our products will meet the shock level stated in the proposed rules, and we suggest the wording be clarified to allow ECCN 6A993.a. cameras to remain under EAR control as long as they meet the related civil automotive requirements currently in place for civilian passenger land vehicles.

Regarding the proposed removal of License Exception STA eligibility for technology classified under ECCN's 6E001, 6E002 and 6E994, Autoliv has successfully ensured related export compliance through the proper use of License Exception STA with our eligible customers, our affiliate companies in Sweden, Germany, and Canada, and our Canadian national employees. Use of that license exception should remain available for our eligible employees and affiliate companies. License Exception STA also should remain available for our eligible customers in order to permit the parties to verify the quality of the products' design and manufacturing for end use in civilian passenger land vehicles. Our customers must have the ability to tour our facility and verify quality requirements for our cameras, optics, electronics, and integration of the IRFPA, all of which is limited to ECCN 6E001 and 6E002 technology for cameras (we do not share with our customers sensor technology controlled under ECCN 6E001 or 6E002, or ROIC technology controlled under ECCN 6E990). That need has been met – and can continue to be met - in a successful and compliant manner through the use of License Exception STA.

In addition, Autoliv designs and develops software for the manufacture, testing, and operation of our ECCN 6A993.a. cameras. We likewise have used License Exception STA in a successful and compliant manner to meet related needs with our affiliate companies in Sweden, Germany, and Canada, and our Canadian national employees. License Exception STA should remain available for this purpose as well.

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IV. Conclusion

The current Category XII(c) and related EAR provisions have worked in an effective manner to ensure export compliance with our customers, employees, and affiliate companies. Autoliv's products include strong and effective anti-tamper features to disable our cameras when removed from the civilian passenger land vehicles for which they have been designed and are used. We hope that DDTC and BIS will either reduce the current controls for our civil automotive cameras, or at a minimum maintain the current language in the ITAR and EAR. Thank you for your attention to these comments and suggestions. Please contact Richard Seoane at (805) 562-5930 or richard.seoane@autoliv.com if you have any questions concerning this letter.

Sincerely,

Richard Seoane
General Manager
Autoliv Electronics Night Vision

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From: Zimmer, Justin (US)
To: DDTCPublicComments
Subject: ATTN: Regulatory Change, USML Category XII
Date: Tuesday, July 07, 2015 11:02:53 AM

Comments submitted by BAE Systems, Inc.

In our meetings with the team members involved with USML XII products, the one cause for concern is the phrase "greater than ###" in USML XII and "less than ###" in ECCN 6A615 as it pertains to focal plane arrays (FPAs). For example:

- USML XII(c)(3) reads: One-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 640 detector elements
- CCL ECCN 6A615.g reads: Combat vehicle, tactical wheeled vehicle, naval vessel, or aircraft pilotage systems or equipment incorporating a variable field of view or field of regard, and incorporating a photon detector-based infrared focal plan array having less than 640 elements.

Neither the USML or CCL addresses "equal to 640", and some of our FPAs are at 640. This makes it unclear as to which regulation 640X480 microbolometer FPAs are controlled. Therefore, the consensus is that the language should be changed to include "equal to" in the regulation to which it pertains. If "equal to" is added to the USML, then we can determine that the 640X480 FPAs will remain export-controlled by State; if "equal to" is added to the CCL, then the 640X480 FPAs will move to Commerce.

From:	Eric Bergles
To:	DDTCPublicComments
Subject:	re: "ITAR Amendment—Category XII." (BaySpec, Inc.)
Date:	Monday, June 22, 2015 4:02:35 PM
Attachments:	image002.jpg

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

June 22, 2015

To Whom It May Concern:

BaySpec, Inc.**,** founded in 1999 with 100% manufacturing in the USA (San Jose, California), is a vertically integrated spectral sensing company. The company designs, manufactures and markets advanced spectral instruments, including UV-VIS-NIR-SWIR spectrometers, benchtop and portable NIR/SWIR and Raman analyzers, confocal Raman microscopes, hyperspectral imagers, mass spectrometers, and OEM spectral engines and components, for the R&D, biomedical, pharmaceuticals, chemical, food, semiconductor, health monitoring, human & animal medical devices, fiber sensing, and the optical telecommunications industries.

Direct comparison of non-military products with USML entries are listed here:

1. We observed that the paragraph 12(c)(2) will classify unsealed linear array devices as ITAR, making the devices we receive from InGaAs vendors which are assembled into higher level fully enclosed channel monitors and fiber grating sensors interrogators, controlled items (see attached datasheets). To date, over the last 12 years, BaySpec has shipped over 40,000 such devices to the commercial telecom and fiber sensing markets. These devices provide a critical piece of the world's internet background and are used for vital structural health monitoring purposes.

2. We also note that arrays with over 640 elements linear array will also become ITAR. BaySpec received arrays with 640 or more elements from InGaAs vendors, which are assembled into higher level spectrometers for biomedical optical coherence tomography (see attached OCT-NIR datasheet) for ophthalmology.

3. We are reviewing the HSI product definitions too about the multi-spectral controls: "Multispectral IRFPAs in Permanent Encapsulated Sensor Assembly Ø Wavelength exceeding

1,500nm but not exceeding 30,000nm". BaySpec is not yet manufacturing hyperspectral imagers over 1500 nm, but have received strong customer interest, as longer wavelengths would naturally provide rich chemical information. If we manufacture in the future, these hyperspectral imagers would be targeted for use by our current customers in precision agriculture, pharmaceutical, and geological/mining survey markets.

For all products above, the target markets were for commercial applications and not specifically designed or in funded by or for military/defense/space purposes.

BaySpec also offers these same products to the military/defense market as commercial off-the-shelf (COTS) devices. Some of our customers include *Harris Corporation*, *NASA, General Dynamics AIS*, *Raytheon*, *Northrop Grumman* and the *U.S. Department of Defense*. If the new proposed changes come into effect, the cost for products will go up substantially to our domestic contractors and ultimately hurt the already strained U.S. budget and taxpayer burden.

BaySpec has international competitors that also source and assemble arrays into final products which are commercially available on the open market, so any additional ITAR classification will present U.S. based BaySpec with an undue burden of compliance adding extra costs and making U.S. products less competitive. A few examples of our competitors, *Ibsen Photonics* (Denmark, www.ibsenphotonics.com) manufacturers FBG interrogators using the same detectors, *Specim* (Finland, www.specim.fi) makes high pixel count hyperspectral imagers, *Horiba Scientific* (Japan/France, www.horiba.com) makes custom spectrometers using linear and two-dimensional arrays. BaySpec believes that the proposed wording will reduce incentives to buy made in USA products while greatly helping our foreign competitors.

The proposed rules, as such, would impact over 90% of BaySpec's product revenue. As a small business, BaySpec does not have the resources to fundamentally restructure its business in this highly competitive marketplace.

In conclusion, BaySpec suggests the following:

- Proposal should be fundamentally rewritten
- Specially Designed should be fully applied to this Category
    - As opposed to performance parameters
- USML should align with the Wassenaar Munitions list

If you require any further information, please contact me on behalf of BaySpec at (408)512-5960 or via email at ebergles@bayspec.com.

Best regards,

Eric Bergles

VP Sales & Marketing

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Description: BaySpec-new logo-25%

Optical Channel Performance Monitor

IntelliGuard® *OCPM Series*

BaySpec's OCPM Series Optical Channel Performance Monitor is an embedded, integrated spectrum analyzer delivering precise measurement and powerful processing capabilities for dense wavelength division multiplexing (DWDM) applications.

The device covers C and/or L band wavelength ranges and provides simultaneous measurements of up to 160 channels spaced 50 GHz apart. High reliability (GR-63/1209/1221 qualified) is achieved through a rugged mechanical design with no moving parts. Periodic calibration is not required. Input/Output (I/O) is provided through a dual port RAM interface accessed through ADD/DAT bus direct connection or serial (RS232 or USB) communications.

The *IntelliGuard*® OCPM Series employs a highly efficient Volume Phase Grating (VPG®) as the spectral dispersion element and an ultra-sensitive InGaAs array detector as the detection element, thereby providing high-speed parallel processing and continuous spectrum measurements. As an input, the device uses a tapped signal from the main data transmission link through a single mode fiber, then collimating it with a micro lens. The signal is spectrally dispersed with the VPG®, and the diffracted field is focused onto an InGaAs array detector. The control electronics read out the processed digital signal to extract required information. Both the raw data and the processed data are available to the host through the chosen interface.

Key Features:

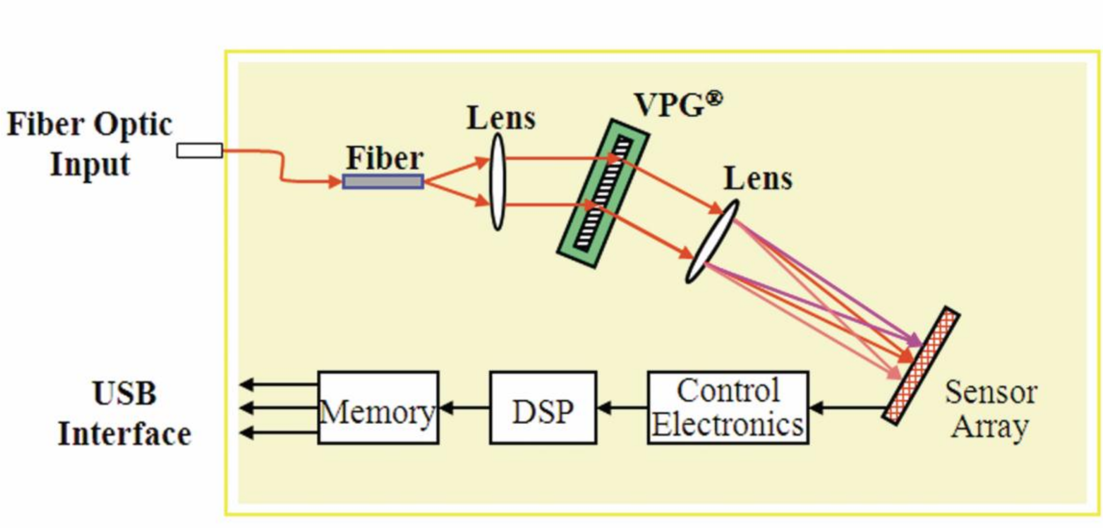
- Real-time <1 ms response time for raw data
- Remote gain equalization of DWDM networks based on optical power or OSNR
- High dynamic range - 50 dB
- High reliability - no moving parts and GR-63/1209/1221 qualified
- Athermal design for ultra-low power consumption
- Compact for new system space constrained environments 68 x 96 x 15.8 mm^3; legacy designs available upon request
- Supports different modulation schemes for 10/40/100 GHz transmission

Applications:

- EDFA gain balancing
- Optical add/drop monitoring
- Physical layer monitoring for provisioning and commissioning optical networks
- Real time fault detection and isolation in DWDM systems
- Channel power, wavelength and OSNR measurement
- OEM module for field test equipment

Compliance

- Telcordia GR-63/1209/ GR-1221 qualified



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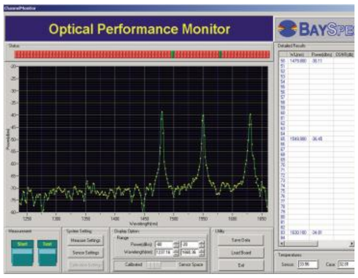
Optical Channel Performance Monitor

IntelliGuard® OCPM Series

Parameter	Data	Unit
Wavelength Range	C or L-band	
Number of Channels	40, 80, 160 or specify	#
Channel Spacing	100, 50 or specify	GHz
Absolute Wavelength Accuracy	± 50	pm
Relative Wavelength Accuracy	30	pm
Channel Input Power Range	-65 to –15 or specify	dBm
Channel Power Accuracy	± 0.5	dB
Power Resolution	0.1	dB
PDL	0.3	dB
Response Time	<50 processed data (<1 raw data only)	ms
OSNR	25	dB
OSNR Accuracy	± 2	dB
Size	68 x 96 x 15.8*	mm^3
Interface	USB, RS-232 or Dual-port RAM	
Weight	<260	g
Power consumption	<2 W max*	W

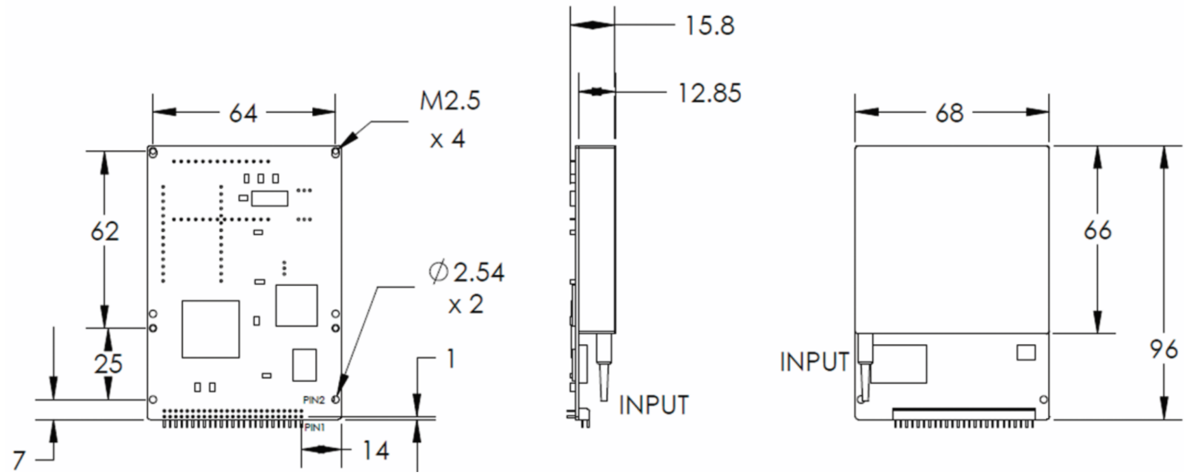
*Subject to Change, Depending on specifications

Sense 2020 Software



BaySpec's *Sense 2020* software included, a Windows-based package with flexible data acquisition, processing and output functionality

BaySpec SDK, a software development kit for new applications development and integration into to your host software systems.



Part Number Selection:

OCPM-□□□-□□□-□□□□-□□

Code	Channel Spacing
100	100 GHz
050	50 GHz
xxx	TBD

Code	Channel Number
040	40
080	80
160	160
xxx	TBD

Code	Starting Wavelength
Please specify the shortest wavelength i.e. :	
2955	1529.55 nm

Code	Connector
NC	None
FA	FC/APC
FP	FC/PC
SA	SA/APC
SP	SA/PC
LA	LC/APC
LP	LC/PC
XY	TBD

Note: OSNR reporting optional
Standard fiber length is 1.0m

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High Speed FBGA Analyzer

WaveCapture® FBGA Series

BaySpec's *WaveCapture*® FBGA Interrogation Analyzer is an integrated spectral engine simultaneously covering multiple wavelengths for precise and Rapid Fiber Bragg Grating (FBG) sensor system measurements.

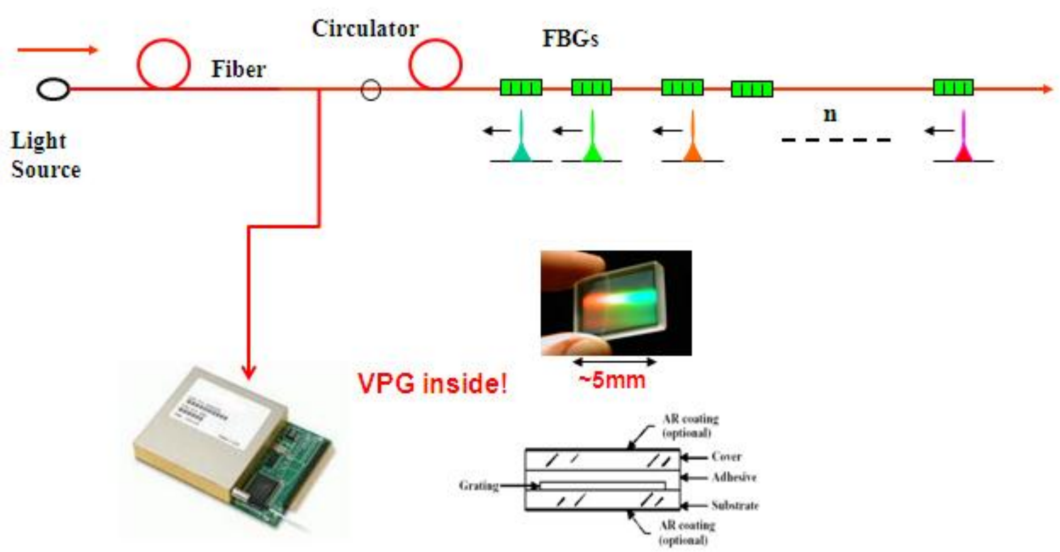
The device covers wide wavelength ranges and provides simultaneous measurements at very fast response rates and excellent wavelength resolution. High reliability (MIL STD 810F shock and vibration) is achieved through a rugged mechanical design with no moving parts. Periodic calibration is not required. High speed Input/output (I/O) is achieved through the use of USB2.0 communications (serial communications also supported at lower speeds).

The *WaveCapture*® FBGA Series employs a highly efficient Volume Phase Grating (VPG®) as the spectral dispersion element and an ultra-sensitive InGaAs array detector as the detection element, thereby providing high-speed parallel processing and continuous spectrum measurements. As an input, the device uses a tapped signal from the main data transmission link through a single mode fiber, then collimating it with a micro lens. The signal is spectrally dispersed with the VPG®, and the diffracted field is focused onto an InGaAs array detector. The control electronics read out the processed digital signal to extract required information. Both the raw data and the processed data are available to the host.

Key Features

- Wide wavelength range
- Ultra-fast response time (up to 5kHz)
- Excellent wavelength repeatability and resolution
- Athermal design enabling battery-operated portable operation
- High reliability for use in harsh environment
- Compact, card-mountable design

Fiber Bragg Grating (FBG) Sensing



Consider using with:

- Mini-Wide Light Sources
- ASE Light Sources
- Fiber-optic Bundles & Accessories

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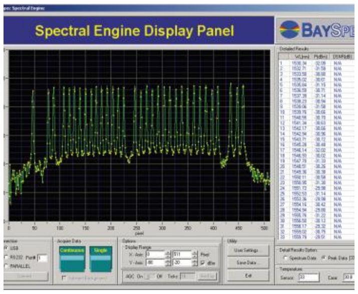
High Speed FBGA Analyzer

WaveCapture® FBGA Series

Specifications	Data	Unit
Standard Wavelength Ranges*	Standard: 1525-1565 Extended: 1510-1590	nm
Wavelength Repeatibility	± 5	pm
Wavelength Readout Resolution	1	pm
Minimum Detectable Wavelength Change	± 1	pm
Frequency response time (typ.)	Standard: ~5 Hz (RS232/USB1.1) Fast: ~5 kHz (USB2.0)	
Channel Input Power Range	-60 to −20 or specify	dBm
Power Resolution	0.1	dB
Size	96 x 68 x 15.8	mm^3
Interface	RS232 or USB (Fast board USB only)	
Operating Temperature	-5 to +70	°C
Software	BaySpec's *Sense 2020* evaluation software included, SDK for development	

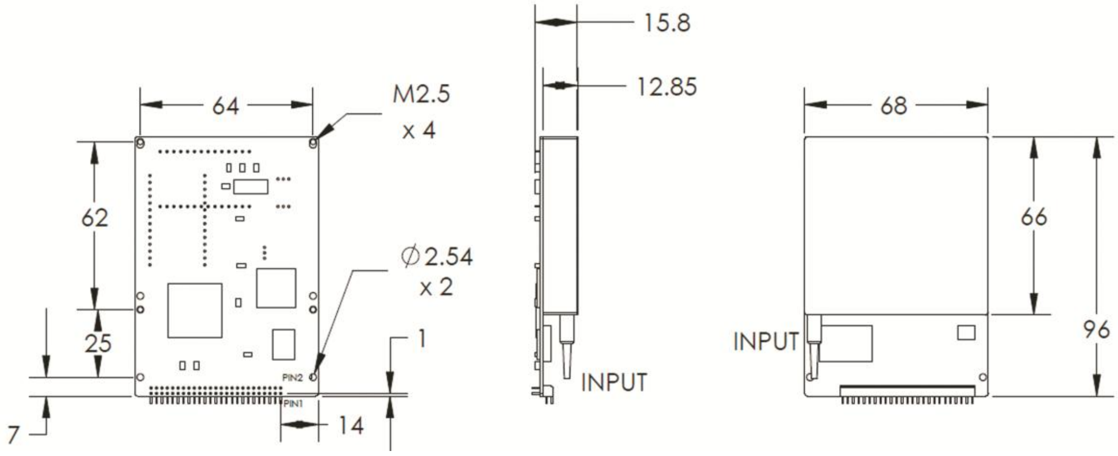
* Other wavelengths available upon request

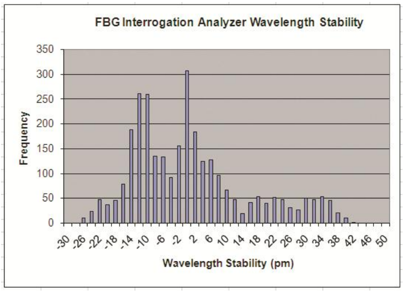
Sense 2020 Software



BaySpec's *Sense 2020* software included, a Windows-based package with flexible data acquisition, processing and output functionality

BaySpec SDK, a software development kit for new applications development and integration into to your host software systems.





Order Info for Part Number:

FBGA - □ - □□□□ - □□□□ - □□

Frequency Response
Specify response time:
S Standard (~5Hz)
F Fast (~5kHz)

Starting Wavelength	
Specify the starting wavelength i.e. :	
1280	1280.00nm
1525	1525.00nm
1510	1510.00nm
Or specify	

Ending Wavelength	
Specify the ending wavelength i.e. :	
1320	1320.00nm
1565	1565.00nm
1590	1590.00nm
Or specify	

Code	Connector Type
NC	No connector
FA	FC/APC
FP	FC/PC
SA	SC/APC
SP	SC/PC
LA	LC/APC
LP	LC/PC
XY	TBD

Note: standard length 1.0m

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Spectral Domain OCTS Engine

DeepView® OCT Long-wavelength Series

OCT Lone-wavelength Series spectral engine shown with example camera

BaySpec's all new *DeepView*® Fourier or Spectral-Domain OCT Spectral Engine is an InGaAs line scan camera with an integrated *VPG*®-based Spectrograph simultaneously covering multiple wavelengths for precise and rapid optical coherence tomography measurements.

The *DeepView*® Spectral Engine provides convenience for researchers and OEM users assembling fourier or spectral-domain optical coherence tomography (SD-OCT), white light interferometry (WLI) or VIS-NIR spectroscopy systems. This flat-field spectral analyzer design is based on highly efficient transmission *Volume Phase Grating* (VPG®) and mounts on an ultra-fast digital line scan camera. The spectral engine accepts single-mode fiber optic inputs and is customizable via grating inserts to match the spectral bandwidth and center wavelength of the users' light source.

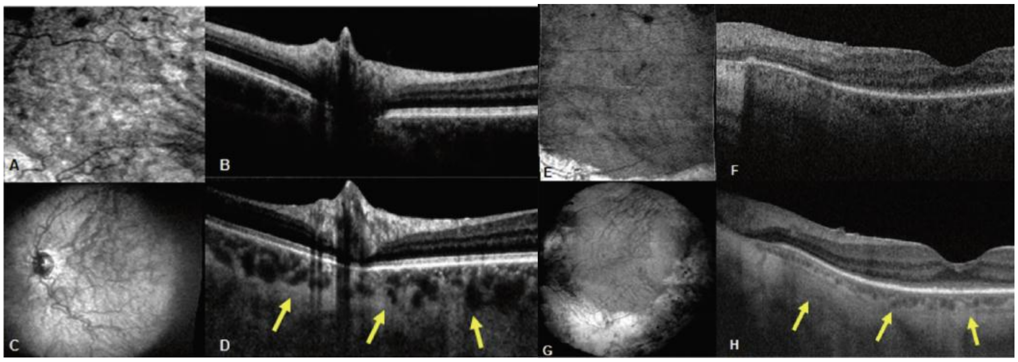
The OCTS NIR Series spectral engine employs a highly efficient *Volume Phase Grating* (VPG®) as the spectral dispersion element and an ultra-sensitive InGaAs array detector as the detection element, thereby providing high-speed parallel processing and continuous spectrum measurements. The signal is spectrally dispersed with the *VPG*®, and the diffracted field is focused onto an InGaAs array detector. The control electronics read out the processed digital signal to extract required information. Both the raw data and the processed data are available to the host.

Applications:

- High-speed spectral OCT for cancer detection in the biologically interested wave bands of 0.8-2.2 μm range
- High-resolution NIR spectral OCT in retinal diagnostics and measurements in ophthalmology
- Spectral OCT guidance on implant and surgery
- High speed and fast turn-around Spectral OCT assessment of surgical outcome
- Catheter/Endoscopic SD OCT image guided diagnostics, image-guided surgery, and image-guided therapy
- In vivo and in vitro general medical diagnostics and imaging
- In vivo and in vitro operation room and surgical procedure Quality Assurance
- Non-invasive skin cancer and skin disease diagnostics and detection
- Industrial applications such as non-destructive testing

Key Features:

- Rugged and reliable spectrometer featuring no moving parts
- Highly-efficient, high-resolution Volume-Phase Grating®
- Flexible options for center wavelength and spectral bandwidth, selectable at time of order; contact factory for custom solutions and packaging with NIR camera.
- Grating and optical bench customizable for your light source and application
- Single-mode fiber coupled inputs; other input fiber options available



3D Optical Coherence Tomography (OCT) at 800 and 1060nm of (A)–(D); a normal retina and (E)–(H) a patient with retinitis pigmentosa. (A, E) En-face zoomed-in fundus image of the choroid using 1060nm 3D OCT. Arrows indicate enhanced choroidal visualization. (Courtesy Cardiff University)

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Spectral Domain OCTS Engine

DeepView® OCT Long-wavelength Series

Parameter	Specification
Optical	
Image plane size [1]	26 mm wide
Optical spot size (single mode fiber)	25 µm diameter
Aperture (f#)	f/4
Focal length (nominal)	100 mm
Mechanical	
Length x Width x Height:	260 x 240 x 116 mm^3 Height includes fiber mount and camera mounting plate size subject to change based on specifications
Weight:	< 800 g (spectrograph only) < 450 g (camera)
Fiber optic interface	Keyed FC/APC (inquire about PM or alternate types)
Camera compatibility	SU1024LDH2-1.7RT-0500/LC, inquire on other types
Camera mount	Optional

[1]with single-mode fiber input (core diameter of 9 µm)

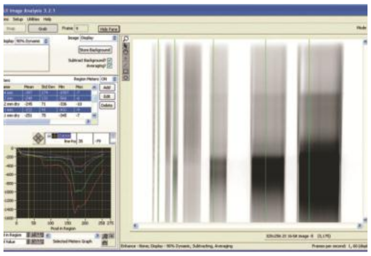
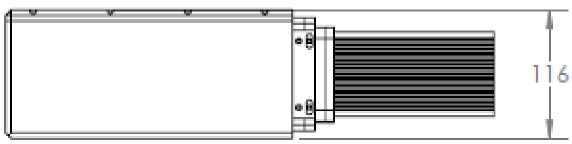
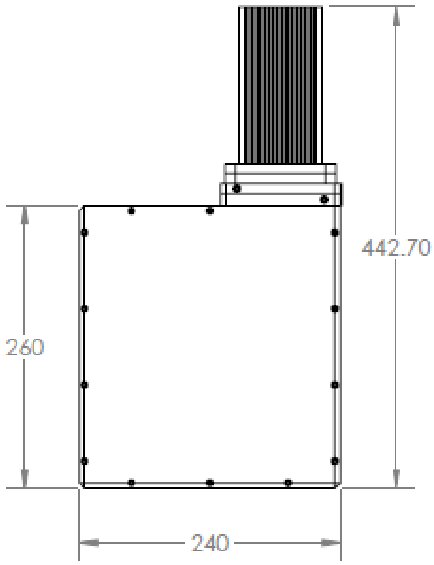


Image Analysis Software with each spectral engine purchase





Note: picture shows example camera only. All in mm.

Consider using with:

- Fast Digital Line Scan Cameras, we can customize to any available model
- Mini-Wide Light Sources
- ASE Light Sources
- Fiber-optic Bundles & Accessories

Ordering Information:

(grating options – ordering suffix[2], other options by request)

	-1280-1310-1340
Center wavelength (nm)	1310
Bandwidth (nm) [3]	60 or custom
Wavelength range (nm)	1280 (0px) – 1340 (~1024px)
Wavelength dispersion (nm_{avg}/pixel) [4]	0.05
Wavelength dispersion (nm_{avg}/mm)	1.95
Stray light(% of peak 100 pixels away[5]	0.1%

[2]Spectrometer model number is OCTS-XXX-YYY-ZZZ; Replace YYY with nominal center wavelength; replace XXX with starting wavelength; ZZZ for ending wavelength
[3]Over 20 mm image plane
[4]With 10 µm pixel pitch
[5]Test laser wavelengths used: 800 nm, as appropriate for grating option selected

Specifications are subject to change without notice

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May 28,2015

To: DDTCPublicComments@state.gov
From: Bill Roor waroot23@gmail.com

Subject: ITAR Amendment - Category XII

Relationships to Wassenaar Dual Use List

Two of the four singles in the original Export Control Reform Initiative were a single control list and a single agency to administer the controls. Proposed USML Category XII goes a long way in the opposite direction.

The following relationships between USML Category XII and CCL ECCNs to comply with the Wassenaar Dual Use List are technically so close as to suggest they should be controlled by only one agency, rather than two. The Department of Commerce has staff in BIS with many years of experience in these technologies. BIS would have to retain such staff. Only portions of these items would be transferred to DDTC in the Department of State. It would be needlessly expensive to duplicate this expertise in DDTC.

This analysis is incomplete. It may omit some commodity overlaps and does omit all related software and technology. The extent of the USML/CCL overlap for software and technology is particularly unclear, largely because "directly related" in XII.f is not defined but also because software and technology is largely common for two technically closely related commodities, one on the USML and the other on the CCL.

Regardless of agency jurisdiction in the United States, the technical descriptions in the proposed USML Category XII indicate levels of military significance which could be put to good use in Wassenaar negotiations to revise its Dual Use List.

It is recommended that each of the following portions of proposed USML XII (and others like them) be removed from that proposal and, instead, be incorporated in U.S. proposals to revise the Wassenaar Dual Use List:

USML XII	CCL ECCN
b.6	6A008.j
b.7	6A008.d
b.8.iv	6A008.j.2
b.10	6A005.c.3.b, d.1.b.2
b.11	6A005.d.1.a.2
b.12	6A005.d.1.b.3
b.13.i	6A005.d.1.d.1.d
b.13.ii	6A005.d.1.d.2.d

b.13.iii	6A005.d.1.d.3.b
b.13.iv	6A005.d.1.d.3.b
c.1	6A002.a.3.g.1, 6A615.d
c.1.i	6A002.a.2.a.3.a
c.1.ii	6A002.a.2.a.3.b,c
c.2	6A002.a.3.f
c.7	6A002.a.3.b.2.b, a.3.g.3, 6A615,g
c.8	6A002.a.3.b.2.b
c.9	6A002.d.2
c.10,11	6A004.d.3
c.12.i	6A002.c.1, 6A003.b.3
c.12.ii, iii	6A002.c.2, 6A003.b.4.a,b
c.12.v,vi	6A003.b.4.b
c.12.viii,x	6A003.b.4.b
c.12.xi	6A002.c.2
c.16.iv	6A002.a.3.g.3, 6A615.g
c.17	2A984
c.19	6A002.a.3.g.1, 6A615.d
d.1*	7A003
d.2	7A001.a.1.a, a.1.b
d.3	7A002
d.4	6A007.b
d.5	6A007.c
d.6.ii	7A005.a
d.6.iii	6A008.e
d.7,8	7A005.b and7A105 (as revised per MTCR recommendation below)
e.1	6A004
e.2.i	6A002.a.2.a.2.a, a.2.b.2.a, a.2.c.1
e.2.ii	6A002.a.2.a.3.a
e.2.iii	6A002.a.2.a.3.b,c, a.2.b.3, a.2.c.3
e.2.iv	6A002.a.2.b.2.b, a.2.c.2
e.2.vii	6A002.d.3
e.4.iii	6A002.a.3.f
e.4.iv	6A002.b
e.7.i	6A002.d.2.a
e.8	6A002.d.2.b
e.9	6A004
e.10,11	3A001.c.3, 4A003 Note 1
e.13	3A001.b.7

* In XII.d.1 Note delete

> "For aircraft and unmanned aerial vehicle guidance or navigation systems, see USML Category VIII.e."

Instruction 2, on page 25825 of the May 5, 2015 Federal Register, proposes to remove and reserve Category VIII.e.

Relationship to 0A987 and 0E987

Proposed XII.a.1 fire control and XII.f for XII.a.1 could be construed to cover all of 0A987 and 0E987. This is because all of the sub-items of WML 5 are under the WML 5 heading of "fire control, and related (items)." In order to brighten the distinction between 0A987 and 0E987 and USML XII, it is reommended that

1. "for weapons controlled on the USML" be added to the heading of USML Category XII;
2. "not controlled by USML Category XII" be added to the headings of 0A987 and 0E987.

Missile Technology

Change "MT" to the MTCR citation plus references to CCL ECCNs which cover the portions of the MTCR items not controlled by the USML and add to those ECCNs "not controlled by (the relevant USML citation),"as follows:

b.4 MTCR 2.A.1.d and11.A.3; ECCNs7A117, 7A005, 7A105

(The MT description in XII.b.4 targeting and guidance omits the MTCR 2.A.1.d guidance set accuracy of equal to or less than 3.33% of range. 2.A.1.d overlaps not only XII.b.4 but also many other parts of XII.a, b, and d. Even so, 2.A.1.d is broader than all these parts of XII combined, because of other limiting features therein which are not included in 2.A.1.d.
The MT portion of XII.b.4 (for "missiles") as it relates to XII.d on GNSS is consistent with MTCR 11.A.3.a for "missiles." For comments on 11.A.3.b, see d.6 below.)
(Therefore, it is recommended that:
7A117 be revised to delete "These items are subject to the ITAR" and to insert "not controlled by USML XII" after "Guidance sets.")

b.6, b.7, b.8 MTCR 11.A.1; ECCNs 6A008, 6A108.a, 7A006, 7A106

(There is no MT problem re b.6,7,8 in the proposed rule.)

(It is recommended that:

1 7A106 be revised to delete "These items are subject to the ITAR."

2. Since XII.b.6,7,8 make no mention of altimeters and 7A006 makes no mention of ITAR and absent a clarification to the contrary, there appears to be no need to add "not controlled by USML XII.b.6,7,8" to the 7A006 or 7A106 altimeter controls.)

c.16.ix No MTCR item found

(<u>It is recommended</u> that MT be deleted from c.16.ix.)

d.1 MTCR 9.A.7; ECCN 7A103.c

(MTCR 9.A.7 is limited to navigational accuracy 200 m CEP or less)

(<u>It is recommended</u> that MT be revised to include navigational accuracy 200 m CEP or less and be moved from d.1 to d.1.i.)

d.2 MTCR 9.A.3, 9.A.5; ECCNs 7A001, 7A101

d.3 MTCR 9.A.4; ECCNs 7A002, 7A102

(MT missing from proposed rule)

(<u>It is recommended</u> that MT be added to d.3.)

d.4 MTCR 12.A.3.a; ECCNs 6A007.b, 6A107.a

d.6, d.7 MTCR 11.A.3; ECCNs 7A005, 7A105

(d.6.i, is for military application, which comes from MTCR 11.A.3.b.2; but the high speed MT description of d.6.i comes from MTCR 11.A.3.b.1 which omits military application.)
(d.6.ii encryption or decryption comes from MTCR 11.A.3.b.2 which includes for military or governmental services but includes only decryption, omitting encryption.)
(d.6.iii null steering antenna and d.7 anti-jam come from MTCR 11.A.3.b.3; but the proposed rule omits an MT description and 11.A.3.b.3 is broader than d.7.)
(d.6.iv is substantively the same as MTCR 11.A.3.a.)

(Therefore, <u>it is recommended</u> that:

1 d.6.i be revised to apply to high speed instead of military;
2 d.6.ii be amended to apply to encryption or decryption for military applications;
3 b.4 MT be expanded to apply not only to “missiles” but also to airborne applications at speeds in excess of 600m/s, decryption for military or governmental services, or anti-jam features;
4 7A005 heading “after (GNSS) receiving equipment” insert:
“not controlled by USML XII.b.4 or d.6"
5 7A005 Related Controls delete:
“(2) For equipment “specially designed” for military use, see Categories XI and XV of the U.S. Munitions List (22 CFR 121)”

6 7A105 heading be revised to apply to MTCR 11.A.3.b.3 “not controlled by USML XII.d.6.iii or d.7” instead of to MTCR 11.A.3.b.1
7 7A105 Related Controls delete:
“(2) See Categories XI and XV of the U.S. Munitions List (22 CFR 121.1) for controls on similar equipment “specially designed” for defense articles.”)

f. for b4 & d6 MTCR 2D3, 2E1, 11D2, 11E2; 7D101, 7E001,2, 7E101

f. for b6,7,8 MTCR 11D1, 11E2; 6D002, 6D102, 7D101, 6E001,2, 6E101,2, 7E001,2, 7E101

f. for c16ix No MTCR item found

f, for d1,2,3 9D1,3,4, 9E1; 7D002,3, 7D101, 7D102b,c, 7E001,2,3, 7E101

f. for d4 12E1; 6E101

Relationships to Wassenaar Munitions List

WML 5 includes the following which are not included in the March 5 proposed rule for USML Category XII:
5.b data fusion, sensor integration equipment (broader than XII.e..11.ii)
5.c countermeasure equipment for WML 5.a or 5.b (broader than XII.d.7, d.8)
5.d field test or alignment equipment specially designed for WML 5.a, 5.b, or 5.c.

Conversely, unlike the existing USML Category XII, the following portions of proposed Category XII are not limited by “for military use” (or the rough equivalent “for defense articles”) and are, therefore, broader than WML 5:
XII all of .a
XII.b except b.8.vi, b.9, b.14
XII.c except c.10, c.16.ix, c.21
XII.d except d.9
XII all of .e
XII.f for the above

Specially designed

The proposed Category XII text uses the non-technical phrase “specially designed” 48 times. This is much more frequently than in any of the other ECR-revised USML categories. Any use of “specially designed” on the USML deviates from the ECR positive list objective. The following indicates how most of the 48 uses could be removed:

1. Components described in XII.a-d,f (all of which should more logically be included in components sub-category XII.e):

9 specially designed parts and components therefor
(a.1, a.8, a.8.i, c.1, f Note 1, c.14, c.15, c.20, d.6)
All 9 could simply be deleted. They would then all be covered by 6A615.x. The result would be an increase in control. This is because the ITAR b.3 release from the catch-all definition of “specially designed” is broader than the EAR b.3 release and the EAR order of review giving a priority to USML coverage would mean that the stricter EAR control would apply under the proposed rule. To the extent applicable, alternatives to deletion would be to substitute technically described components or to change “specially designed parts and components therefor” to “components having the characteristics described therein.”

12 specially designed to incorporate:
(a.2, b.4 (2x), b.6, b.8.i, b.8.iii, c.13, Note 1 to c.13, c.14, c.15, c.16, Note 1 to f)
One wonders why it should be necessary to control all these items when they do not actually incorporate the component of concern. However, to the extent that this may be justified, it can more reasonably be accomplished by deleting “specially,” so that the releases in the definition of “specially designed” would not apply if the item is, in fact, designed to incorporate the component of concern. On the other hand, neither specially designed nor designed could, from a practical standpoint, be determined for a.2.ii or b.6 (any article subject to, or controlled by, this subchapter) or c.14, c.15, or c.16 (any article controlled in this category). Moreover, it makes no sense for a.2 to control an item specially designed to incorporate various components of concern but not to control an item which actually incorporates those components of concern.)

1 cooler having dewar specially designed for XII.a, b, or c
(c.9.iv)

1 specially designed electronics and optics therefor
(c.12)
Change “specially designed” to “application specific”

2 specially designed electronics, optics, and displays therefor
(c.13, c.16)
Change “specially designed” to “application specific”

25 subtotal, components described in XII.a-d.f

2. <u>Components described in component sub-category XII.e,f:</u>

1 specially designed optics and electronics therefor
(e.1)

Change “specially designed” to “application specific”

1 electron sensing devices specially designed for operation with a microchannel plate
(e.2.iv)
Change “specially designed” to “application specific”

2 phosphor screens or fiber-optic inverters specially designed for image intensifier tubes controlled in this category
(e.2.v, e.2.vii)
Technical description may be adequate to permit deletion of “specially designed.”

4 Read-Out Integrated Circuits (ROICs) specially designed for a c.2 IRFPA or for a camera/core/packaged IRFPA controlled by this subchapter
(e.4, Note to e.4, e.5, f Note 1)
Change “specially designed” to “application specific”

1 Sealed enclosure for a XII.c IRFPA or IIT specially designed for XII.a, b, or c
(e.6)
Technical description may be adequate to permit deletion of “specially designed.”

1 IRFPA dewar cooler <218 K, MTTF >3,000 hours, active cold fingers, variable or dual aperture, and dewars specially designed for XII.a, b, or c
(e.7.iv)
Technical description may be adequate to permit deletion of “specially designed.”

1 IRFPA Joule-Thomson self-regulating cryostats specially designed for articles controlled in this subchapter
(e.8)

Technical description may be adequate to permit deletion of “specially designed.”

3 Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings; drive, control, signal or image processing electronics; and near-to-eye displays specially designed for articles controlled in this category
(e.9, e.10, e.12)

14 subtotal, components described in component sub-category XII.e

3. <u>End-items:</u>

1 Remote wind-sensing specially designed for ballistic-corrected aiming
(a.8)
Technical description may be adequate to permit deletion of “specially designed.”

1 LIDAR specially designed for obstacle avoidance or autonomous navigation in
Category VII ground vehicles.
(b.8.vi)
Technical description may be adequate to permit deletion of “specially designed.”

1 infrared imaging systems specially designed for military platforms in VI, VII, or VIII
(c.16.ix)
Change “specially designed” to “developed”
(The word “developed” is the only part of paragraph (a)(1) of the definition of “specially designed which can be applied to the word “military.”

1 near-to-eye displays specially designed for articles controlled in this subchapter
(c.18)

1 Systems incorporating IR beacon specially designed for Identification Friend or Foe
(c.20)
Technical description may be adequate to permit deletion of “specially designed.”

4 GNSS receiving equipment specially designed for military applications; encryption or decryption; use with a null steering antenna; or use with rockets, missiles, SLVs, drones, or UAVs
(d.6.i,ii,iii,iv)
Change “specially designed” to “developed” for military applications.
Technical descriptions may be adequate to permit deletion of “specially designed” for encryption, null steering antenna, and use with rockets or UAVs.

9 subtotal, end-items

48 total

The Boeing Company
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July 6, 2015

Mr. C. Edward Peartree, Director
Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
Department of State
SA–1, 12th Floor
Washington, DC 20522–0112.

Subject: RIN 1400-AD 32; Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

Reference: Federal Register/ Vol. 80, No. 86/ Tuesday, May 5, 2015/ Proposed Rules

Dear Mr. Peartree,

The Boeing Company ("Boeing") appreciates the opportunity to provide comments on controls proposed for Category XII of the United States Munitions List ("USML"). We strongly support the Export Control Reform effort and the Directorate of Defense Trade Controls ("DDTC") work to more precisely describe the articles warranting control on the USML. We have identified several issues where proposed International Traffic in Arms Regulations ("ITAR") controls could impact items in normal commercial use. Boeing does not manufacture these items so is not positioned to recommend alternative technical thresholds, but recommends that the stakeholder agencies use the technical advisory committees for assistance including an understanding of global and commercial availability.

Our comments address definitions, laser distance measuring devices, microbolometers, GPS receiving equipment, Global Navigation Satellite System receiving equipment, null steering antennas, and guidance and navigation systems used on commercial satellites.

1. <u>Definitions</u>

Controls related to certain proposed listings are not clear as some key technical terms are not defined in the control text. Page 25832 of the Federal Register Notice provides definitions to "explain and amplify terms used in this Category and are provided to assist exporters in understanding the scope of the proposed control." They include 'charge multiplication', 'focal plane array', 'image intensifier tube', 'microbolometer', and 'multispectral'. It is unclear whether these definitions will be incorporated into the ITAR.

Definitions for the terms 'rangefinder' and 'target' would also assist in compliant interpretation. We propose a definition for 'rangefinder' in our comment 3 below. The term 'target' has several definitions, including: *"something or someone fired at or marked for attack"*

(Merriam Webster online dictionary). However, it can also refer to an item or phenomenon that is the subject of study or concern. For example, a number of optical instruments in normal commercial use will use devices called 'targets'.

Recommendations:

- Include the definitions provided in the discussion section of the Proposed Rule either as standalone definitions in Part 120 of the ITAR or as notes in Category XII.
- Provide definitions for 'rangefinder' (see comment 3 below) and 'target' that distinguish the ITAR-controlled items from the commercial usage, or use qualifiers in the control text such as **military** target.

2. Fire control, weapons sights, aiming, and imaging systems and equipment, XII(a)(4) Note

The Note concerning LIDAR controls leaves out certain corresponding controls in paragraph (b).

Recommendation:

Revise the Note as follows: For controls on LIDAR, see paragraphs (b) ~~(9)~~ **(6-9)** of this category.

3. Laser Distance Measuring Devices, XII(b)(3)

The proposed regulatory text is:

(b)(3) Laser rangefinders having any of the following:
(i) Q-switched laser pulse; or
(ii) Laser output wavelength exceeding 1,000 nm;

No definition for 'rangefinder' is provided. The Merriam-Webster dictionary definition is:

1**:** an instrument used in gunnery to determine the distance of a target
2**:** a surveying instrument (as a transit) for determining quickly the distances, bearings, and elevations of distant objects
3**:** a usually built-in adjustable optical device for focusing a camera that automatically indicates the correct focus (as when two parts of a split image are brought together)

Without additional detail, this listing could capture commercial rangefinders using laser light. Boeing does not manufacture such devices, but Boeing and many other manufacturers use laser interferometers, laser radar scanners, and laser theodolites to measure distances in surveying and in factory settings. Applications include the measurement of commercial aircraft aerodynamic symmetry, alignment of production elements, verification of production tooling accuracy, design of one-off custom parts, etc.

Some of the devices in common commercial use exceed the wavelength threshold in the proposed listing. For example, the 3D laser scanner 'Surphaser Model 105HSX', marketed by a company in Redmond WA, has a laser output of 1550 nm. Product details are at http://www.surphaser.com/pdf/Surphaser%20105HSX.pdf. Given the important role of laser rangefinders in commercial production processes, narrowly scoped controls that do not capture items in commercial use are critical.

Recommendation:
Provide a qualification in the control listing or a definition for 'rangefinder' that differentiates military applications from commercial usage. For example: ***'rangefinder' in this category means an instrument used in gunnery to determine the distance of a military target.***

4. Microbolometers, XII (c)(2)

Many items currently controlled in the Export Administration Regulations under 6A002 would move to ITAR control due to the broad proposed control for unencapsulated focal plane arrays. A listing of particular concern is that for XII(c)(2).

The proposed regulatory text is:

> (c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;

Boeing uses low-cost thermal imaging cameras for a host of applications in our factory environment including: temperature profiling, non-destructive inspection, and facilities checks to detect issues such as steam traps, electrical faults and failures, etc. To perform these tasks, we use cameras incorporating microbolometers operating in the 3,000-12,000 nm wavelength range. These cameras make use of focal plane arrays ("FPA") that are not encapsulated. Because the cameras contain FPAs described by (c)(2) and there are no element number thresholds in (c)(2) – as are found in (c)(12) - the cameras would have to be protected as ITAR items in accordance with the "see through rule". The cameras Boeing uses are currently classified as 6A003(b)(4), because they contain focal plane arrays controlled by 6A002(a)(3)(f). Such products are commercially available from companies such as the FLIR Corporation and are ubiquitous in industrial use. Control of such products on the USML is inconsistent with the objectives of export reform.

Recommendation:
Add a note to (c)(2) such that non-encapsulated FPAs incorporated into cameras are controlled in (c)(12), which has an element number threshold that will not capture these commercial items:

> ***Note to (c)(2): Non-encapsulated FPAs meeting the description contained in this listing and incorporated into cameras are subject to (c)(12) only.***

5. GPS Receiving Equipment, XII(d)(6)(iii) and Note

The proposed regulatory text is:

> (d)(6)(iii) GPS receiving equipment specially designed for use with a null steering antenna, an electronically steerable antenna, or including a null steering antenna designed to reduce or avoid jamming signals (MT if designed or modified for airborne applications);

GPS signal jamming equipment is widely available for purchase within the United States. These devices disrupt GPS systems such as cell phone and automotive systems within range of the jamming signal. Numerous models are available from sites such as: http://www.cellphone-jammers.org/GPS-Jammers-For-Sale.html

Although such jammers do not have great range, there have been instances of commercial aircraft systems being impacted at airports by signals from these jammers. With the proliferation of such devices, there will be increasing interference in the GPS signal band impacting both commercial and military aviation. The most practical solution is the application of null steering antennas to the commercial GPS receiving devices. Although null steering antennas and signal security systems for use on commercial aircraft are not yet commercially available, they are not inherently military. With continually increasing security threats to commercial airplane communications, those applications will soon arrive in the U.S. and elsewhere, as Boeing has explained in previous comments submitted on Category XI.

It appears some relief is offered by the (d)(6)(iii) exclusionary Note:

> *Note to paragraph (6)(iii):* The articles described in this paragraph are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR. Articles do not become subject to the EAR until integrated into the item subject to the EAR. Export, reexport, retransfer, or temporary import of, and technical data and defense services directly related to, defense articles intended to be integrated, remain subject to the ITAR.

However, freeing control of the GPS receiver designed for use with a null steering antenna does little to enable use of such devices in EAR controlled applications because the antennas they are used with are likely covered by Category XI:

> (c)(10) Antenna, and specially designed parts and components therefor, that:
> (i) Employ four or more elements, electronically steer angular beams, independently steer angular nulls, create angular nulls with a null depth greater than 20 dB, and achieve a beam switching speed faster than 50 milliseconds;
> (ii) Form adaptive null attenuation greater than 35 dB with convergence time less than one second;
> (iii) Detect signals across multiple RF bands with matched left hand and right hand spiral antenna elements for determination of signal polarization; or
> (iv) Determine signal angle of arrival less than two degrees (e.g., interferometer antenna);

The "see through rule" would apply to the antenna application such that that the end item containing the antenna would need to be protected as ITAR-controlled regardless of the exclusion for the receiver itself.

Recommendation:
Eliminate the (d)(6)(iii) control on GPS receiving equipment and retain control of the capability using the null steering antenna control in Category XI.

6. Dual Coverage of Null Steering Antennas, XII(d)(7)

The proposed regulatory text is:

> (d)(7) GNSS anti-jam systems employing adaptive antennas that have a minimum of four antenna elements, add 35 dB or greater anti-jam margin, and produce nulls in the direction of jammers or high-gain beams in the direction of satellites at any ranging code frequency;

The basis of this listing is the use of antennas that can direct the beam and the null to achieve 35dB or greater anti-jam margin. This technology is not specific to GNSS systems but rather with processing of signals received by the antenna. The XII(d)(7) listing thus creates dual coverage for items also captured by XI(c)(10) shown in comment 5 above. These systems are more logically placed in the general control of XI(c)(10).

Recommendation:
Delete (d) (7) and retain control over such antennas under Category XI.

7. Guidance, navigation, and control systems and equipment, XII(d)(1) and (3)

The (d)(1) and (d)(3) proposed listings, as currently written, capture space-qualified[1] guidance and navigation systems currently used on commercial satellites controlled under the EAR. For example, Miniature Inertial Measurement Units (MIMUs) are currently classified as 7A003.d.2 but are also captured by XII(d)(1) and (3). However, the MIMUs used in commercial satellites are designed and built with higher radiation hardening requirements and other elements commonly used on space qualified hardware. Furthermore, items captured by (d) are available outside the United States. For example, the space qualified Astrix 200 made by Airbus Defence and Space (see http://www.space-airbusds.com/en/equipment/astrix-200.html) already has better performance than several of the specified thresholds in (d)(3) such as true north determination (if products were used for north finding), Angle Random Walk, Bias Stability and Drift Stability.

Recommendation:

- Revise the threshold values in XII(d) to avoid capture of MIMUs as follows: Bias Stability: <0.0003 deg/hr (3-sigma); ARW <0.0002 (3-sigma); True North Determination calculated as (bias stability) / (15.04 deg/hr earth rate): <20 micro-radians (3-sigma); Drift stability in 1g environment (same thing as bias stability): <0.0003 deg/hr (3-sigma).

[1] Per the definition of space qualified provided in Note 3 to XV(e).

- Alternatively, add language to the Note for paragraph (d)(1) to exclude guidance, navigation and control systems used on commercial satellites. Add a new, similar note for (d)(3).

  Note to paragraph (d)(1): **This provision does not apply to items that are space qualified as defined in XV.** For aircraft and unmanned aerial vehicle guidance or navigation systems, see USML Category VIII(e). For rocket or missile flight control and guidance systems (including guidance sets), see USML Category IV(h).

  Note to paragraph (d) (3): **This provision does not apply to items that are space qualified.**

8. Note to paragraph XII(d)(1)

There seems to be an error in the Note to paragraph (d)(1) in this phrase: “For aircraft and unmanned aerial vehicle guidance or navigation systems, see USML Category VIII(e)”. This needs to be updated as USML Category VIII(e) is removed and reserved per the amendatory note 2 on p. 25825 of the Federal Register Notice.

Thank you for the opportunity to provide comments. Please do not hesitate to contact me if you have any questions or need additional information. I can be reached at 703-465-3505 or via email at christopher.e.haave@boeing.com.

Sincerely,

Christopher Haave
Director, Global Trade Controls

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Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0033
Comment on DOS-2015-0027-0001

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General Comment

GPS/GNSS adaptive antennas will provide benefits to counter the threats of intentional/unintentional interference and spoofing for civil aviation. While this is true from an anti-jam perspective to provide detection and possible localization capabilities in addition to the ability to maintain sustainable signal levels for receiver track, the ability to perform beamforming (in addition to nulling) supports current civil GPS requirements of code-carrier continuity of track, augments availability in addition to minimizing the impact of jammer and spoofer threat. Techniques such as linear constrained minimum variance beamforming may be used to achieve this goal. In fact, plain vanilla nulling could cause adverse impacts to tracking and the overall availability. Rockwell Collins requests the addition of the following notes to (d) (6) and (d) (7):

Note to paragraph (d)(6): This paragraph does not control GPS receiving equipment specially designed for use with a null steering antenna, an electronically steerable antenna, or including a null steering/beamforming antenna designed to reduce or avoid jamming signals for civil aviation applications.

Note to paragraph (d)(7): This paragraph does not control GNSS anti-jam/beamforming systems for civil aviation applications.

Bristow

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July 6, 2015

Mr. C. Edward Peartree
Director, Office of Defense Trade Controls Policy
U.S. Department of State
PM/DDTC, SA-1, 12th Floor
2401 E Street, N.W.
Washington, DC 20037

Subject: ITAR Amendment – Category XII/RIN 1400-AD32
Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, Specifically Category XII(c)(16)(i)

Dear Mr. Peartree:

Introduction

Bristow Group Inc. ("Bristow") appreciates the opportunity to comment on the proposed revisions to Category XII of the United States Munitions List ("USML"), Part 121 of the International Traffic in Arms Regulations ("ITAR"). 80 Fed. Reg. 25821 (hereafter "Proposed USML Category XII"). Bristow appreciates the Directorate of Defense Trade Controls' ("DDTC") engagement with the industry as part of the Export Control Reform Initiative.

While Bristow welcomes a positive-list approach to the Proposed Category XII, we believe that the revisions will continue to capture items which are now in normal commercial use. As an operator of civilian aircraft for search and rescue ("SAR") operations, Bristow uses electro-optical/infrared ("EO/IR") systems, which include forward-looking infrared sensors, installed on aircraft in the normal course of business provided to our customers. As set forth in more detail below, Bristow believes that those EO/IR items described in amended Category XII(c)(16)(i) should be moved from ITAR to the Commerce Control List ("CCL") of the Export Administration Regulations ("EAR").

Bristow and SAR Operations

Bristow Group

As the first civilian helicopter transport company to work in the oil and gas industry, Bristow has provided transportation, production management and related services for 60 years. The company offers point-to-point scheduled and charter transportation services, combining fixed-wing with rotary-wing services to clients around the world. In addition to providing helicopter transport services for energy companies and others, Bristow is a leader in SAR services.

Bristow

Bristow's fleet of consolidated and unconsolidated helicopters includes almost 500 civilian helicopters (including light, medium and heavy aircraft).

SAR Operations

Bristow operates private sector SAR services in Australia, Canada, Norway, Russia, Tanzania and Trinidad, and public sector SAR services for the entire land and adjacent waters of the United Kingdom on behalf of the Maritime and Coastguard Agency ("MCA") of the U.K. Department for Transport ("DfT").

UK SAR Program

In 2012, Bristow Helicopters Ltd. ("Bristow UK," a U.K. affiliate of Bristow) was awarded a contract, known as the "GAP SAR U.K. Contract" to provide civilian search and rescue helicopters services from two bases in the United Kingdom on behalf of the U.K. DfT and its MCA. In 2013, the contract was extended to 10 U.K. bases. Under the full U.K. SAR contract, Bristow UK will operate 22 aircraft from 10 bases across the United Kingdom, strategically located near areas of high SAR incident rates. The contract runs until 2026.

Bristow UK's services for the DfT/MCA are purely civilian in nature. The MCA is an executive agency of the U.K. DfT, and it has no military or law enforcement function.[1] Bristow UK has a long history of providing SAR services in the United Kingdom, dating back to 1971. In total, Bristow UK has flown more than 44,000 SAR operational hours in the United Kingdom and conducted over 15,000 SAR missions, during which more than 7,000 people have been rescued by the company's crews and helicopters.

Bristow has led the industry in introducing new aircraft types and technology to the civil market. The SAR equipment it has developed has become the industry standard, resulting in Bristow UK being recognized with the Queen's Award for Innovation for its technical developments.

Private SAR

In response to recent incidents in safety, oil and gas industry leaders have increased their efforts to be equipped for accidents by securing SAR coverage for their operations. Given Bristow's existing relationships with these oil and gas industry leaders and Bristow's depth of experience in SAR, we have been awarded contracts for private SAR services. For these oil and gas industry clients, Bristow supplies a dedicated SAR helicopter and crew to cover exploration projects in remote areas. It requires specific expertise to conduct SAR operations, and Bristow has been a world leader in SAR for years, with experienced pilots, aircrew, paramedics, engineers and ground crew to conduct SAR operations safely and reliably.

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[1] The definition of "armed forces" under Section 130.3 refers to "the army, navy, marine, air force, or coast guard as well as the national guard and national police, of a foreign country." Bristow believes that the reference to "coast guard" in Section 130.3 refers to an organization that performs in part military and law enforcement functions similar to the other military services. For example, the U.S. Coast Guard, which is presently under the Department of Homeland Security, states on its website that it is one of the nation's "five military services", and that it is a "military, multi-mission, maritime force offering a unique blend of military, law enforcement, humanitarian, regulatory, and diplomatic capabilities." Its missions include "port and waterway security", "defense readiness", drug interdiction", and "law enforcement". Based on that review, Bristow's U.K. affiliate's search and rescue services for the U.K. DfT and MCA are not "for the use of the armed forces of a foreign country."

SAR-Equipped Helicopters

In order to meet the demands of its customers, Bristow uses a variety of SAR-equipped helicopters, including the Sikorsky S-76, Sikorsky S-92[2], AgustaWestland 139, AgustaWestland 189, and H225 aircraft, all of which, in their standard configuration, are civilian aircraft.

The industry standard minimum requirement for a SAR helicopter is the hoist, which is capable of lifting the rescuer and victim at the same time. The aircraft is also equipped with a flight management system, which flies the aircraft over a pre-programmed search grid at sea. Additional basic SAR equipment includes emergency flotation devices on the skid landing gear, weather radar, and a PA system. However, these minimum equipment requirements are only effective for daytime SAR missions.

To perform nighttime and all weather SAR missions, the SAR helicopter must be equipped with equipment to assist in less-than-ideal flying conditions, such as low visibility, nighttime, and inclement weather. The main requirement for these SAR helicopters—in addition to the equipment mentioned above— is a de-icing system, specific navigation and search equipment, and extra medical equipment for taking care of survivors. Specifically, to perform nighttime SAR missions, the helicopter must be equipped with a forward looking infrared camera which can be incorporated into an EO/IR system, powerful external lighting, a searchlight, and a cockpit that is compatible with the use of night vision goggles.

To perform SAR operations 24 hours a day/7 days a week in any weather and on any terrain, helicopters must be equipped with an EO/IR system incorporating forward looking infrared sensors and thermal imaging camera technology.[3] See Attachment B which details technology used on Bristow SAR helicopters.

Bristow SAR helicopters[4] are currently equipped with an EO/IR system. Additionally, future purchases of SAR helicopters will require the installation of an EO/IR system on the helicopters.

EO/IR Systems

Bristow Use of EO/IR Systems

Bristow's use of EO/IR systems has been solely for commercial purposes, i.e. to provide civilian SAR services to customers. In fact, in the course of Bristow's review of EO/IR system manufacturers, it was apparent that EO/IR systems are used on many civilian SAR operations around the world, including aircraft and sea vessels. Some of the SAR operations using EO/IR systems include the Royal Canadian Mounted Police[5], Norwegian Society for Sea Rescue[6],

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[2] See Attachment A for a diagram of a SAR-equipped S92 for use in Bristow's contract with the U.K. MCA.
[3] Bristow's SAR operations also include the use of night-vision goggles (NVGs) by pilots and crew. While NVGs are currently on the USML and the proposed revisions to Category XII, Bristow does not intend to comment on the classification of NVGs.
[4] Bristow also operates "Limited SAR" ("LIMSAR") helicopters. LIMSAR helicopters are not equipped with an EO/IR system. LIMSAR helicopters are also considered part of Bristow's SAR operations.
[5] http://www.airbushelicopters.com/w1/jrotor/71/rcmp.html
[6] http://www.flir.eu/marine/display/?id=42090

Irish Coast Guard (operated by CHC Helicopters)[7], Japan Coast Guard[8], Norway Ministry of Justice and Public Safety[9], and China's Ministry of Communications - Shanghai Salvage & Rescue Bureau[10].

Bristow's SAR services, both private and public, cover a variety of terrain and conditions. For many private SAR customers, Bristow SAR helicopters must be equipped to perform SAR operations over large stretches of water to reach oil and gas platforms and alternative landing sites. Additionally, over half the coverage area for the SAR services provided to the U.K. MCA is over water.[11] The EO/IR system allows the crew, and particularly the winch men, to pan over the water to look for distressed persons. Due to the difference in temperature between a human and the water, the infrared sensing capabilities of the forward-looking infrared sensors allow the crew to locate persons in the water from the aircraft, particularly where rough seas are encountered.

Similarly, for SAR operations over land, the benefits of the EO/IR system cannot be overstated. On rock, mountainous terrain, when it is difficult to maintain visibility on the distressed persons, the EO/IR system allows the crew to easily detect the person(s) on the ground. Once detected, instruments on the EO/IR system permit the crew to automatically maintain focus on the person(s), while the crew is able to prepare the winch.

An EO/IR system's performance heavily depends on stabilization and the image resolution, both of which are crucial to SAR operations. The stabilization capability of the EO/IR system counteracts the intense vibrations and motion of the aircraft to provide a clear image in the system viewer. Crews on the SAR helicopters require a high level of stability to locate distressed persons from far distances and in inclement weather conditions. To perform the rescue, the crew must track the distressed person as the aircraft positions for the rescue operation. Without a high level of stability, the tracking requires more time, when time is of the essence.

The measure of resolution refers to the number of pixels on an imaging component of the EO/IR system. An increase in the pixels improves the image quality and equips the crew with a clearer view of the scene. With the visual information from the image, the crew can quickly strategize on the most effective rescue operation.

Time is of critical importance in SAR operations particularly where the helicopters are required to operate to their maximum range which limits time available in the rescue area due to fuel constraints. Mere seconds can make the difference between life and death. Bristow's crews use the EO/IR systems to quickly search for distressed persons and track them in preparation for a rescue mission. Countless lives have been saved with the use of this technology. Due to confidentiality agreements with its customers, Bristow is unable to share details of SAR missions performed. Suffice to say, the EO/IR systems have been a vital to the success of our SAR operations in saving lives.

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[7] http://www.chc.ca/news/2015/01/irish-coast-guard-completes-record-number-of-missions-with-new-helicopter-fleet.aspx

[8] http://www.helis.com/database/news/aw139_jpcg_3/?desktop=1

[9] http://www.aviationtoday.com/rw/public-service/SAR/Norwegian-SAR-AW101s-to-Get-FLIR-Star-Safire-Sensors_82511.html#.VZP2300o670

[10] http://www.defense-aerospace.com/article-view/release/3860/china-orders-two-sikorsky-s_76%2B-for-sar-(dec.-13).html

[11] See Attachment C – Map of U.K. SAR Territory.

EO/IR System Purchases

Since at least 2002, Bristow has purchased and operated U.S. and foreign manufactured EO/IR systems on SAR helicopters. Based on the manufacturer's assessment, EO/IR systems are captured on the current version of USML Category XII(c). For this reason, Bristow has taken the necessary measures to ensure compliance with DDTC licensing and compliance requirements.

Depending on the destination of the aircraft, the origin of the EO/IR system, and the aircraft manufacturer, Bristow will require the EO/IR system to be exported and outfitted to the aircraft in several different ways. When using a foreign aircraft manufacturer, Bristow purchases the EO/IR system directly from the system manufacturer. The EO/IR system manufacturer exports the system to the location in which it will be fitted to the aircraft and/or the end-use destination of the SAR aircraft. In those cases, the EO/IR system manufacturer obtains the export license. In those cases, the EO/IR system manufacturer may be a foreign manufacturer or U.S. manufacturer.

Alternatively, when working with U.S. aircraft manufacturers, the EO/IR system is shipped to the aircraft manufacturer and fitted to the aircraft in the U.S. Once the aircraft is equipped with the EO/IR system and delivery is made available to Bristow, Bristow is responsible for obtaining the export license for the aircraft, which includes the EO/IR system.

Bristow currently owns or operates the following EO/IR systems on its SAR aircraft:

- FLIR Systems, Inc. Star Safire III (U.S. manufacturer)
- FLIR Systems, Inc. Ultra 4000 (U.S. manufacturer)
- Wescam MX-15HDi Surveillance System (Canadian manufacturer)

Comments

In response to the request in paragraph (4) of the "Request for Comments" portion of the preamble to the Proposed USML Category XII, Bristow submits these comments to "provide specific examples of items…that would be controlled by the revised USML Category XII…that are now in normal commercial use."

As outlined above in our description of services, Bristow uses EO/IR systems and technology commercially to provide civilian SAR services to our customers around the world. We believe the EO/IR systems used by Bristow, currently captured by USML Category XII(c), would be included under the Proposed Category XII, specifically XII(c)(16)(i). For those items, which Bristow has identified as currently in commercial use, we strongly recommend that such items be transferred to the CCL of the EAR.

Administrative Burden

Due to the nature of Bristow's business, sharing technical data related to the EO/IR system is required. For this reason, Bristow must prepare Technical Assistance Agreements ("TAA") for the release of technical data associated with EO/IR systems. The process for securing approval on a TAA from DDTC includes drafting the TAA, review by all parties to the TAA, submission to the DDTC, and, if the TAA is approved, obtaining signatures by all the parties to the TAA before export pursuant to the TAA can be undertaken. Additionally, Bristow must obtain nationality information and perform screening on all employees who may be given access to the technical data. Protective measures must be put in place to ensure no unauthorized access to the technical data. Compliance plans and training must be performed as part of the protective measures. Once the TAA is executed, the actual export licenses (DSP-5 or DSP-73) must then be applied for.

To apply for and obtain the necessary export licenses (whether temporary or permanent) usually takes several weeks to months, depending on the complexity of the purchase. Furthermore, because of the value associated with the purchase of several aircraft, Congressional Notification may be required for permanent exports of the civilian aircraft with the EO/IR equipment installed. While Bristow has thus far been successful in obtaining the necessary export licenses, there have been instances in which the approval has come uncomfortably close to Bristow's contractual deadlines for delivery of the helicopters.

Moreover, due to the nature of the helicopter services industry, the lead time on a commercial opportunity may only be presented several weeks in advance. Bristow is unable to offer its services without certainty that it will be able to obtain the necessary DDTC approval in time for the performance of services. These delays can put Bristow at a strategic disadvantage relative to its foreign competitors.

Moving the EO/IR systems used for SAR operations to the CCL would allow Bristow to more quickly react to industry demand and compete on an equal footing with foreign providers of SAR services. While DDTC has indicated that the average processing time for a license is between 25-29 days since January 2015[12], Bristow has experienced a wider variation in processing times, including over 40 days for a license application to be processed, in addition to the lengthy process of having a TAA reviewed, approved, and executed. According to BIS's Annual Report to the Congress for Fiscal Year 2014, BIS processes licenses in an average of 23 days.[13] Exports of technical data under the CCL would not require an executed TAA prior to application for a license to export thus eliminating the additional time required for TAA execution. Additionally, the CCL offers license exceptions that would potentially be available for Bristow's exports, making the export process more efficient by eliminating the requirement to obtain a license.

System Complexity

Due to the complexity of the EO/IR system and its components, exporting an EO/IR system independent from the aircraft to which it will be equipped is difficult. All aircraft currently used by Bristow for SAR operations are civilian aircraft, listed on the CCL. However, certain models of SAR helicopters must be equipped with an EO/IR system by the aircraft manufacturer. Internal wiring for the EO/IR system is not simple add-on equipment but must be embedded into the aircraft during the manufacturing process. Once the aircraft is equipped with the entire EO/IR system, i.e. external attachments and monitors, the aircraft is then classified under USML Category VIII(a)(11).[14] For this reason, Bristow is required to export the entire aircraft pursuant

[12] http://pmddtc.state.gov/metrics/index.html
[13] Bureau of Industry and Security - Annual Report to the Congress for Fiscal Year 2014, pg. 7.
[14] EO/IR systems are identified as a "mission system" defined in USML Category VIII, Note 1 to paragraph (a)(11), as " 'systems' that are defense articles that perform specific military function such as by providing military communication, electronic warfare, target designation, surveillance, target detection, or sensor capabilities."

to a license obtained from the DDTC, as opposed to obtaining a license only for the EO/IR system.

Removing the EO/IR system, including its parts and components, from the USML would eliminate the requirement that the entire aircraft be included on the USML. This would significantly reduce the burden of moving aircraft globally.

Foreign Availability

EO/IR systems are available by foreign manufacturers. Below is a table of available EO/IR systems in the marketplace:

PRODUCT NAME	COMPANY	COUNTRY OF MANUFACTURE
Star SAFIRE 380-HD[15]	FLIR Systems, Inc.	USA
MX-15[16]	L-3 Wescam	Canada
Toplite EOS[17]	Rafael	Israel
Agile 2[18]	Thales Optronique	France
Euroflir 350[19]	Sagem	France
MOSP-3000HD[20]	Israel Aerospace Industries	Israel
DCoMPASS[21]	Elbit Systems	Isreal
EOST-46[22]	Selex ES	Italy

For some SAR helicopters, Bristow has used foreign manufactured EO/IR systems on foreign manufactured aircraft. For example, the Wescam MX-15 is used on Bristow's H225s. The MX-15 was exported from Canada pursuant to a Canadian export license obtained by the system manufacturer. The use of a foreign manufactured EO/IR system has simplified the global movement of the aircraft and presented opportunities which would not have been available for an aircraft embedded with a U.S.-manufactured EO/IR system since the aircraft in its entirety is not controlled, but simply the EO/IR system. While the ease of movement was not the sole reason for Bristow's choice of a foreign EO/IR system manufacturer, the benefit of a non-U.S. manufactured EO/IR system is apparent.

Bristow believes that U.S. EO/IR system manufacturers would be in a better position to present information on foreign competition and any differences that exist among the products in the industry. As an operator of EO/IR systems, Bristow can attest to the fact that there are foreign manufactured systems that offer the same capabilities as those manufactured in the United States.

Because these EO/IR systems are readily available from foreign manufacturers these systems do not appear to provide a critical military or intelligence advantage to the United States, and thus, we believe the item should not meet the criteria for continued control under ITAR. EO/IR

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[15] http://www.flir.com/surveillance/display/?id=64812
[16] http://www.wescam.com/wp-content/uploads/PDS-MX-15-63133M-July-2014.pdf
[17] http://www.rafael.co.il/marketing/SIP_STORAGE/FILES/8/1278.pdf
[18] https://www.thalesgroup.com/sites/default/files/asset/document/agile_2_a4_en_072012_ref_099a_corrected.pdf
[19] http://www.sagem.com/product/euroflir-350
[20] http://www.iai.co.il/Sip_Storage//FILES/0/41030.pdf
[21] http://elbitsystems.com/Elbitmain/files/DCoMPASS_Special_Missions.pdf
[22] http://www.selex-es.com/documents/737448/17606805/body_mm08114_EOST46_LQ_.pdf

systems described at Category XII(c)(16)(i) that are manufactured in the United States should be moved to the CCL. It is also worth noting that the Wassenaar Arrangement Munitions List (Category 15), does not appear to specifically list an EO/IR system like those described in USML Category XII(c)(16)(i).

Technical Specifications and Parameters

As outlined above, EO/IR systems with stabilization and high resolution imaging capabilities are required to provide adequate civilian SAR services. While they may provide some military function, their normal commercial use and their foreign availability indicate that they do not provide a critical military advantage sufficient to be included on the USML. Instead, higher resolution and stabilization, allow Bristow and other SAR providers to perform better and save more lives. Additionally, safety of the crew is improved with the ability to operate safely in low light and visibility. The resolution and/or stabilization should not be the criteria used to determine whether an EO/IR system is captured on the USML. These criteria are essential to successful SAR missions.

As a purchaser of EO/IR systems for normal commercial use, Bristow is not in a position to comment on what specifications and parameters of EO/IR systems provide a sufficient military advantage to warrant being placed on the USML rather than the CCL. However, Bristow is aware of certain optional functions that are available on EO/IR systems which Bristow has declined to obtain. Bristow believes that some of these functions provide examples of functions that may materially enhance military capability and are less likely to be used in commercial applications. For example, EO/IR systems can be programmed to provide laser-guided munition capabilities and counter-measures. These functions are of no use to civilian SAR operations and would serve as differentiating characteristics of those EO/IR systems that should be captured by the USML.

While Bristow is aware of optional capabilities of EO/IR systems, described above, we are not EO/IR system manufacturers and thus are not completely educated in all the characteristics, specifications and capabilities of all EO/IR systems. While we are able to comment on the civilian use of higher resolution and stabilization for SAR operations, Bristow does not have full knowledge of all other specifications. For this reason, we believe the EO/IR system manufacturers would be in the best position to further comment on what additional parameters would be optimal for differentiating between EO/IR systems that should be on the USML.

EAR Jurisdiction

Bristow recommends that EO/IR systems of the type used for civilian SAR operations which are covered by proposed USML Category XII(c)(16)(i) be moved to the CCL, specifically ECCN 6A003.

Conclusion

Bristow obtains and operates EO/IR systems for normal commercial use. Proposed USML Category XII controls these same EO/IR systems. Bristow believes that EO/IR systems used in civilian SAR operations should be removed from the USML and instead controlled on the CCL for the following reasons:

- Bristow, along with other helicopter operators, use EO/IR systems described under amended Category XII(c)(16)(i) in the normal course of commercial business.
- The EO/IR systems used by Bristow are invaluable to the success of SAR operations and saving lives.
- EO/IR systems used by Bristow are available from foreign manufacturers.
- The complexity and time-consuming nature of ITAR-controlled licensing procedures (including Congressional Notification requirements) hinder Bristow's commercial opportunities.

Thank you again for affording us the opportunity to provide comments. Please do not hesitate to contact me if you have any questions or need additional information. I can be reached at 713-430-7721 or via email at Miriam.eqab@bristowgroup.com.

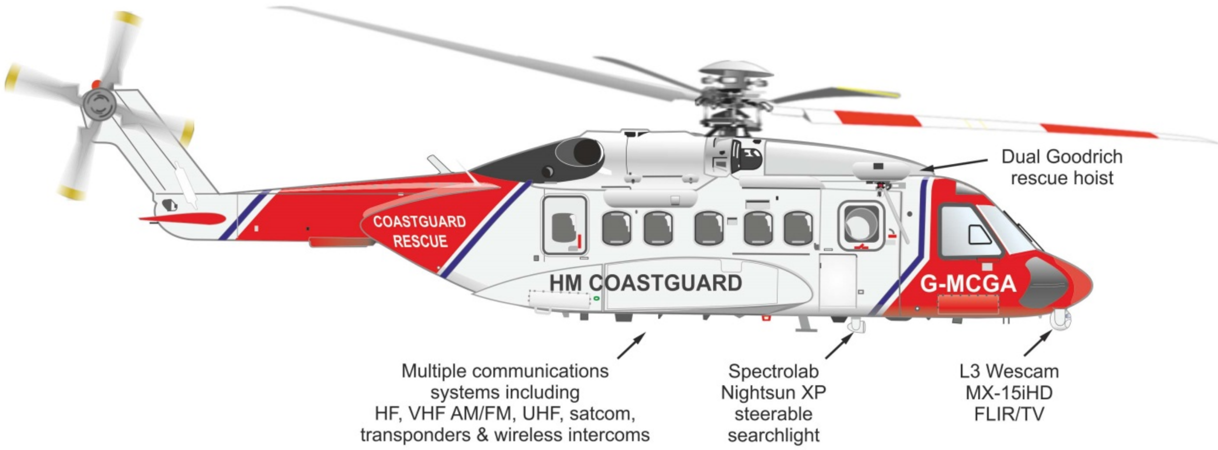
Sincerely,

Miriam Eqab
International Trade Compliance Counsel

Attachment A

Bristow Sikorsky S-92 Helicopter Equipped for U.K. SAR Program with a Wescam EO/IR System

Bristow S.92 Search & Rescue Helicopter



Bristow

<u>Attachment B</u>

Screenshot from Bristow's SAR Website

http://www.bristowsar.com/index.php/uk-search-and-rescue/technology/

Bristow
Search and Rescue

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TECHNOLOGY

- UK SAR
- GAP SAR
- SAR BASES
- FLEET
- TECHNOLOGY
- RECRUITMENT

Technology

Bristow Helicopters has led the industry in introducing new aircraft types and technology to the civil market and the search and rescue equipment developed by the company has become industry standard, resulting in Bristow Helicopters being recognised with the prestigious Queens Award for Innovation for the company's technical developments.

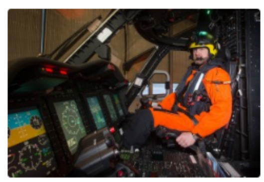
Our new search and rescue helicopters are fitted with a raft of state of the art technology, some of which has never before been used in commercial search and rescue aircraft.

Night Vision Goggles

Bristow Helicopters has gone to great lengths to obtain the necessary International Traffic in Arms Regulations (ITAR) export licence in order to invest in the best possible night vision goggle (NVG) technology available to the civil market for its SAR crews. In terms of civilian operations, Bristow's S-92 SAR aircraft are the first type in Europe to be certified for NVG and have the first "glass cockpit" to be certified NVG compatible. The technology is essential when responding to night time incidents, particularly during the short winter days when operations can extend into the hours of darkness.

Forward-looking infrared (FLIR)

Our SAR aircraft have improved forward-looking infrared (FLIR) and thermal imaging camera technology for more effective searches and high illumination lighting to make winching easier and safer. This is particularly useful when operating in confined spaces or conducting cliff rescues. The long range fuel tanks allow us to operate across the vast distances we are covering.



Wireless communication

The UK SAR S-92s are the first aircraft in Europe to be fitted with Trulink® wireless capabilities for communications between the aircraft and crew, while the wireless intercom system allows winchmen to not only communicate with the aircraft but also to communicate with nearby vessels in the event that they are left behind at the scene. A much improved external public address system allows the SAR crew to communicate more effectively with casualties on the ground below.

Medical capabilities

The medical zone intercom allows the cabin and cockpit to be split into isolated zones, meaning medical teams can work on a patient without the flight crew being distracted. Improved cabin lighting, including emergency white light, will enable advanced medical procedures to be carried out onboard. In addition, the cabins are fitted with 230 volt ac power outlets so that the SAR aircraft can operate advanced medical equipment onboard. Bristow has designed a bespoke cabin layout to accommodate more casualties and medical equipment safely.

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Bristow

<u>Attachment C</u>
Map of Coverage Area for U.K. SAR

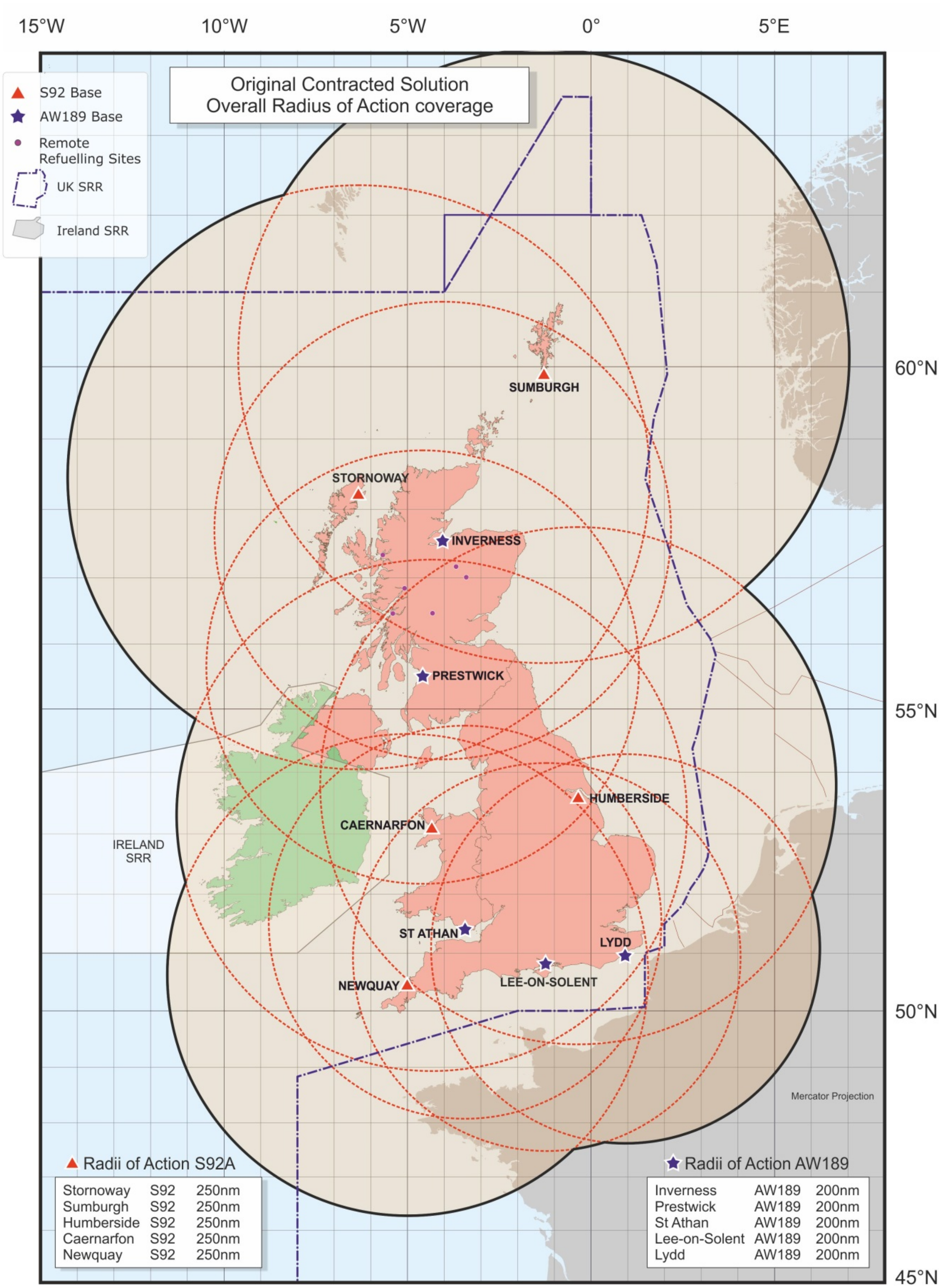

Chart Inc.
1 Infinity Corporate Centre Drive
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www.chartindustries.com

July 2, 2015

C. Edward Peartree, Director

Office of Defense Trade Controls Policy

U.S. Department of State

ATTN: Regulatory Change, USML Category XII

2201 C Street, NW

Washington, DC 20520

Re: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII; Comments on Category XII Paragraphs (c)(9)(i) and (e)(7)(i)

Dear Mr. Peartree:

Chart Inc. (Chart) has recently become aware of the State Department's proposed rule to amend the International Traffic in Arms Regulations (ITAR) to revise Category XII (fire control, range finder, optical and guidance and control equipment) of the U.S. Munitions List (USML) (RIN: 1400-AD32) (the Proposed Rule). This comment addresses specifically the proposed amendments to title 22, chapter I, subchapter M, part 121.1, USML Category XII (c)(9)(i) and USML Category XII (e)(7)(i) (together, the Proposed Addition).

1. Summary of the Issue

The Proposed Addition lacks control criteria that specifically describe items with the potential for use in strategic defense or space applications. On the contrary, the criteria included in the Proposed Addition are common to virtually every modern cryogenic cooler, whether commercial grade or tactical munitions-grade. Commercial-grade cryocoolers do not provide the United States with any military or intelligence advantage and therefore should not be controlled as defense articles. The incorporation of Chart's proposed criteria (discussed throughout and listed in Section 3C) will provide a clear, bright-line, distinction between items in normal commercial use and items properly considered defense articles for control on the USML.

If adopted in its present form, the impact of the Proposed Rule will be substantial, resulting in the imposition of significant costs of compliance. The Proposed Rule will impact manufacturers' costs of production, and cause a consequent loss of exports and jobs. Chart, through its predecessor in interest, Clever Fellows Innovation Consortium, Inc., has been producing and selling commercial-grade cryocoolers for over twenty years. Because Chart and others in the industry have been selling commercial cryocoolers to domestic and foreign end-users for many decades, Chart does not believe that the increased regulatory burden it and others stand to incur will result in a corresponding benefit to United States national security or contribute to the achievement of any military or intelligence advantage.

2. Relevant Text

Following is a citation of the Proposed Additions to USML Category XII paragraphs (c) and (e) with relevant language bolded:

> (c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:
>
> …
>
> (9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:
>
> (i) **Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours**;
>
> (ii) Active cold fingers;
>
> (iii) Variable or dual aperture mechanisms; or
>
> (iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category;

(e) Parts, components, accessories, attachments, and associated equipment as follows:

…

(7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components, as follows:

(i) **Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours**;

(ii) Active cold fingers;

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b) or (c) of this category;

3. Details of the Issue

A. The U.S. government does not want to inadvertently control items on the USML that are in normal commercial use. The public is requested to provide specific examples of items that would be controlled by the Proposed Rule that are now in normal commercial use.

Chart's cryocoolers serve a wide range of applications and have been sold for use in both domestic and foreign locations. Primary consumer end-uses for our cryocoolers include the long-term cold storage of medical and biological samples (e.g., tissues from cancer studies); freeze-point testing of commercial fuels for cold-temperature use; on-site liquefaction of medical oxygen for therapeutic use (e.g., for ambulatory patients with lung disease); education, fundamental physics and cryogenics research; and conversion of cryogenic storage tanks to zero-loss by re-condensation of boil-off vapors. The above-mentioned end-uses for our cryocoolers are real; these are not hypothetical. With the exception of the use of a cryocooler for the conversion of a cryogenic storage tank to zero-loss, which is currently still in development, Chart has sold units for each of the above mentioned end-uses to end-users located in the United States, Japan, China, Russia, Brazil, Israel, and the Czech Republic, among other places.

B. A key goal of the rulemaking is to establish a "bright line" between the USML and the CCL for the control of materials. The public is asked to provide specific examples of control criteria that do not clearly describe items that would be defense articles and thus do not establish a "bright line" between the USML and the CCL.

The Proposed Addition related to cryocoolers in paragraphs (c) and (e) is: "**Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours.**" Commercial cryocoolers, like the type produced by Chart, are not flight-weight, tactical cryocoolers suitable for use in thermal imaging, munitions, or space applications. Yet, each of Chart's cryocoolers, from the smallest to the largest model we offer, meets the criteria of (i) having a cooling source temperature below 218 K, and (ii) a mean-time-to-failure (MTTF) in excess of 3,000 hours. Far from creating a bright line test to distinguish coolers capable of use as defense articles from those designed to meet commercial needs, the Proposed Addition describes two criteria almost every commercial-grade cryocooler meets. Indeed, every cryocooler Chart has sold in the last 20-plus years, for the above-mentioned consumer end-uses, meets the temperature and MTTF criteria set out in the Proposed Addition.

Cryogenic temperatures are critical to enable infrared, gamma-ray and x-ray detectors, and reliable, multi-year cooling is essential for defense, satellite, and space applications. The cryocoolers suited to achieve the intended control objectives of the Proposed Rule are those cryocoolers specially designed to meet the United States' specific military and intelligence needs. This class of coolers can be succinctly described as "SADA-qualified" cryocoolers. The Standard Advanced Dewar Assembly module (SADA), was created by the Department of Defense (DOD) in an effort to standardize second-generation thermal imaging systems and their attendant critical components. The established family of SADAs each comprise an infrared focal plane array (IRFPA), dewar, command and control electronics, and a cryogenic cooler, and each family is designed to address high performance (SADA I), mid-to-high performance (SADA II), and compact class systems (SADA III). The family of cryogenic coolers that support the SADAs are generally Stirling-cycle coolers, and by their very definition these SADA-qualified coolers are suited to meet the DOD's varying standards of low input power, vibration cancellation, low noise, and high reliability.

The criteria included in the Proposed Addition do not appropriately distinguish commercial cryocoolers and those that meet DOD SADA requirements, or even more generally between coolers that reasonably can and cannot be operated to support the infrared (IR) and other focal plane array (FPA) sensors and imaging equipment that are the proper focus of the relevant USML Category XII paragraphs. On the contrary, the Proposed Addition captures cryocoolers that because of inherent limitations in weight, size, input power, and cooling capacity, are not considered by the industry as capable of use in any tactical military, or space application.

Chart's commercial-grade cryocoolers and the family of SADA tactical cryocoolers are similar to the extent that they may be characterized as Stirling-cycle devices, inasmuch as both devices use valveless compressors, or pressure oscillators, to cause cyclic temperature variation in a closed vessel of gas. Ultimately there are more differences than there are similarities, however. One primary difference between Chart's commercial-grade coolers and tactical or munitions-grade coolers, is the fact that SADA cryocoolers are generally displacer-equipped. Meaning, a mechanical displacer within the device is used to separate the heating and cooling effects in relation to the pressure oscillation. Chart cryocoolers – indeed, any "pulse tube" or "acoustic-Stirling" cryocoolers – on the other hand, do not have such displacers. Acoustic-Stirling cryocoolers move hot and cold gas out of phase with the internal pressure through use of a reservoir that stores and returns gas during the operating cycle, by means of the inertial behavior of the gas only. This distinction is notable because acoustic-Stirling devices, like Chart's, require a cold finger configuration that is almost always unacceptable for use in a cryocooler for military or tactical end-use applications. More specifically, because of the presence of the buffer, or "pulse" tube, a larger diameter cold finger and a secondary reservoir tank are required to produce the same refrigeration power as a comparable Stirling-cycle device. These differences simplify construction for cost savings in commercial use, but do not support military functionality. Notably, the larger SADA II-qualified cryocooler must provide a 1-2 Watt capacity at 77K, with a coldfinger that fits within the standard SADA dewar bore of a 0.5-inch diameter. Chart's smallest commercial model, on the other hand (the QDrive® 2s102K cooler), is rated at 6-8 Watts at the same temperature and its coldfinger has a diameter three times that size, at 1.25 inches. For more information about the challenges in conforming acoustic-Stirling (sometimes also called "pulse tube" type) cryocoolers to SADA requirements see, *Pulse Tube Cryocoolers for Cooling Infrared Sensors*, by R. Radebaugh, National Institute of Standards and Technology, attached here as Exhibit A.

Another material distinction, or "bright line", between tactical and commercial-grade coolers is the units' allowable weight. Again, all of Chart's commercial-grade cryocoolers regularly achieve temperatures below 218 K and all have an MTTF in excess of 3,000 hours. Yet, the smallest model we offer, the 2s102K cooler, weighs between 22-26 lbs., depending on the options chosen. Even at the lowest possible end of the spectrum – 22 lbs. – our 2s102K model cooler weighs 14.5 lbs. more that the cryocooler required to meet SADA I requirements, and it is 17.8 lbs. in excess of the cryocooler required to meet SADA II requirements. Weight alone is sufficient to preclude use of commercial-grade cryocoolers in strategic military, or tactical space applications. For more information about the key parameters for SADA family cryocoolers see, *Status of Programs for the DoD Family of Linear Drive Cryogenic Coolers for Weapon Systems*, by W.E. Salazar, attached here as Exhibit B.

Input power is another criterion that could be used to distinguish tactical from commercial-grade coolers. SADA family cryocoolers operate from battery-bus DC voltage, but most commercial-grade cryocoolers connect directly to utility AC power. By way of example, an army qualified SADA II cryocooler will draw 60 Watts through a controller from a battery; whereas, the smallest commercial cryocooler in Chart's offering draws up to 320 Watts from 110 Volts/60 Hz AC power. The maximum allowable input power for any cryocooler in the SADA family is 94 Watts, for a SADA I-qualified cooler, which is far exceeded by most of the smallest commercial-grade models.

C. For any criteria that the public believes will control items in normal commercial use, the public is asked to identify parameters or characteristics that cover items exclusively or primarily in military use.

Because the SADAs capture the distinct technical requirements necessary for cryocoolers for use in tactical military and space applications, Chart suggests that some criteria from the SADAs be incorporated into the Proposed Additions to create the intended "bright line" between defense articles, appropriately controlled on the USML, and items otherwise subject to the EAR. As discussed in more detail above, listed below are the practical criteria that if incorporated into the Proposed Addition would provide a distinction between commercial and munitions-grade, tactical cryocoolers. Chart suggests that the Proposed Additions be deleted and that USML Category XII, paragraphs (c)(9)(i) and (e)(7)(i) be amended to include any combination of these criterion:

i. Stirling-cycle, displacer-equipped cryocoolers
ii. Maximum cooling capacity of 5 Watts at 77K when rejecting to 20C or lower ambient temperature.
iii. Cryocoolers having a coldfinger less than 25 mm in diameter
iv. Cryocoolers weighing less than 10 lbs per unit
v. Cryocoolers with a stated maximum power input of not more than 100 Watts

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vi. Cryocoolers operable from DC electrical input, or a maximum AC voltage not to exceed 50 Volts rms

Chart believes that these criteria are clear and describe appropriate bounds around the characteristics of, and thus limit ITAR controls to tactical, military-grade cryocoolers.

The addition of any combination of the criteria described above will bring the text of USML Category XII closer to established precedent regarding the control of defense articles. Chart believes the deletion of the current criteria and addition of any of those mentioned above will be sufficient to avoid future confusion and will further the Department's goal of creating a bright line between items on the USML and the CCL. Please contact me with any questions. Chart is happy to discuss this further and provide all reasonable assistance in order to achieve approval of our requested amendment.

Sincerely,

John Corey

John Corey

Vice President for Innovation and Engineering

Chart Inc.

1 Infinity Corporate Centre Drive

Garfield Heights, Ohio 44125

EXHIBIT A

Proceedings of SPIE, The International Society for Optical Engineering, Infrared Technology and Applications XXVI, Vol. 4130, pp. 363-379 (2000)

Pulse Tube Cryocoolers for Cooling Infrared Sensors*

Ray Radebaugh

National Institute of Standards and Technology
Boulder, Colorado 80303 USA

ABSTRACT

This paper reviews recent advances in pulse tube cryocoolers and their application for cooling infrared sensors. There are many advantages of pulse tube cryocoolers over Stirling cryocoolers associated with the absence of moving parts in the cold head. Efficiencies have been improved considerably in the last few years to where they equal or even exceed the efficiencies of Stirling cryocoolers. The use of inertance effects and double inlets to improve the efficiencies will be discussed. Pulse tube cryocoolers are now being used or considered for use in cooling infrared detectors for many space applications. One disadvantage of pulse tube coolers is the difficulty in scaling them down to sizes as small as 0.15 W at 80 K while maintaining high efficiency. A second disadvantage is the larger diameter cold finger required for the same refrigeration power because of the presence of the pulse tube. These two disadvantages have limited their use so far in cooling infrared sensors for many military tactical applications. Progress in overcoming these disadvantages is discussed.

Keywords: Cryocoolers, Cryogenics, Detectors, Infrared, Night vision, Pulse tubes, Refrigerators, Review, Sensors, Stirling

1. INTRODUCTION

Small cryogenic refrigerators (cryocoolers) are required for a wide variety of applications, and the number of applications keeps expanding as improvements to cryocoolers are made. One of the earliest applications, and one that appeared about 50 years ago, was for cooling infrared sensors to about 80 K for night vision capability of the military. Over 125,000 Stirling cryocoolers for this tactical military application have been produced to date.[1] Refrigeration powers vary from about 0.15 W to 1.75 W. In the last decade or so the desire for night vision surveillance and missile detection from satellites has prompted much research on improved cryocoolers to meet the very stringent requirements for space use. Each application has a particular set of requirements that have led to many recent improvements in cryocoolers. Still, some of the problems associated with cryocoolers have hampered the marketing of many potential applications. The major problems associated with cryocoolers are listed in Table 1. For satellite applications all but the last problem in Table 1 are of major concern, even though a space-qualified cryocooler can cost $1.0M or more. Lifetimes of 10 years are now standard requirements for most space applications. Until recently efficiencies of 3 to 10% of Carnot were typical of these small cryocoolers, whereas now efficiencies of 15 to 25% of Carnot are now possible.

Table 1. Cryocooler problems.

- Reliability
- Efficiency
- Size and weight
- Vibration
- Electromagnetic Interference (EMI)
- Heat rejection
- Cost

New commercial applications, particularly the use of high temperature superconductors as microwave filters in base stations for wireless communication systems, have stimulated much research on ways to reduce the cost of cryocoolers while still maintaining a lifetime goal of 3 to 5 years. Research on various types of cryocoolers has been carried out with the goal of meeting the requirements for a particular application. As a result, improvements have been made in all the types of cryocoolers. This paper briefly reviews some of the recent advances in pulse tube cryocoolers. More extensive reviews of all cryocoolers[2] as well as pulse tube cryocoolers[3] have been given by the author. The advantages of pulse tube cryocoolers make them natural candidates for the cooling of infrared detectors for both tactical and space applications. Pulse tube cryocoolers are now being developed for many space applications, but the tactical applications have had a particular set of historical requirements that have made it difficult to use pulse tube cryocoolers in place of the Stirling cryocoolers. This paper also discusses some of these problems and how recent advances may make it possible to meet these requirements, at least for larger systems.

2. TYPES OF CRYOCOOLERS

Though the focus of this paper is on pulse tube cryocoolers, a brief introduction of all the cryocooler types is given here because some comparisons will be given later that are more meaningful if there is some understanding of the various types. Figure 1 shows the five types of cryocoolers in common use today. The Joule-Thomson (JT) and the Brayton cryocoolers are of the recuperative type in which the working fluid flows steadily in one direction, with steady low- and high-pressure lines, analogous to DC electrical systems. The compressor has inlet and outlet valves to maintain the steady flow. The recuperative heat exchangers transfer heat from one flow stream to the other over some distance. Recuperative heat exchangers with the high effectiveness needed for cryocoolers can be expensive to fabricate. The three regenerative cryocoolers shown in Fig. 1 operate with an oscillating flow and an oscillating pressure, analogous to AC electrical systems. Frequencies vary from about 1 Hz for the Gifford-McMahon (GM) and some pulse tube cryocoolers to about 60 Hz for Stirling and some pulse tube refrigerators.

2.1 Recuperative Cryocoolers

The steady pressure and the steady flow of gas in these cryocoolers allow them to use large gas volumes anywhere in the system with little adverse effects except for larger radiation heat leaks if the additional volume is at the cold end. Thus, it is possible to "pipe cold" to any number of distant locations after the gas has expanded and cooled. In addition, the cold end can be separated from the compressor by a large distance and greatly reduce the electromagnetic interference (EMI) and vibration associated with the compressor. Oil removal equipment with its large gas volume can also be incorporated in these cryocoolers at the warm end of the heat exchanger to remove any traces of oil from the working gas before it is cooled in the heat exchanger. Unlike conventional refrigerators operating near ambient temperature, any oil in the working fluid will freeze at cryogenic temperatures and plug the system.

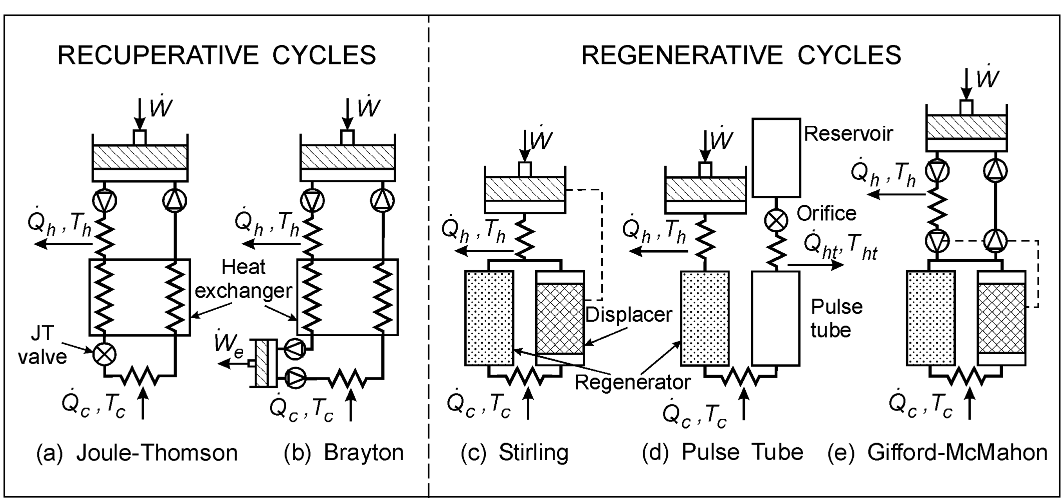

Figure 1. Schematics of five common types of cryocoolers.

2.1.1 Joule-Thomson cryocoolers

The Joule-Thomson cryocoolers produce cooling when the high-pressure gas expands through a flow impedance (orifice, valve, capillary, porous plug), often referred to as a JT valve. The expansion occurs with no heat input or production of work, thus, the process occurs at a constant enthalpy. The heat input occurs after the expansion and is used to warm up the cold gas or to evaporate any liquid formed in the expansion process. In an ideal gas the enthalpy is independent of pressure for a constant temperature, but real gases experience an enthalpy change with pressure. Thus, cooling in a JT expansion occurs only with real gases and at temperatures below the inversion curve. In fact, for a given pressure change the amount of cooling increases as the temperature is lowered and reaches a maximum around the critical point. Typically, nitrogen or argon is used in JT coolers, but pressures of 20 MPa (200 bar) or more on the high-pressure side are needed to achieve reasonable cooling. Such high pressures are difficult to achieve and require special compressors with limited lifetimes.

The main advantage of JT cryocoolers is the fact that there are no moving parts at the cold end. The cold end can be miniaturized and provide a very rapid cool-down. This rapid cool-down (a few seconds to reach 77 K) has made them the cooler of choice for cooling infrared sensors used in missile guidance systems. These coolers utilize a small cylinder pressurized to about 45 MPa with nitrogen or argon as the source of high-pressure gas. In this open-cycle mode, cooling lasts for only a few minutes until the gas is depleted. Figure 2 shows a typical JT cryocooler used for missile guidance. Miniature finned tubing is used for the heat exchanger. An explosive valve is used to start the flow of gas from the high-pressure bottle, and after flowing through the system, the gas is vented to the atmosphere.

A disadvantage of the JT cryocooler is the susceptibility to plugging by moisture of the very small orifice (possibly experienced in a test of the long-range U. S. Missile Defense System in January, 2000). Another disadvantage is the low efficiency when used in a closed cycle mode. Compressor efficiencies are very low when compressing to such high pressures.

Recent advances in JT cryocoolers have been associated with the use of mixed-gases as the working fluid rather than pure gases. The use of mixed gases was first proposed in 1936 for the liquefaction of natural gas[2], but it was not used extensively for this purpose until the last 20 or 30 years. It is commonly referred to as the mixed refrigerant cascade (MRC) cycle. The use of small JT coolers with mixed gases for cooling infrared sensors was first developed under classified programs in the Soviet Union during the 1970s and 1980s. Such work was first discussed in the open literature by Little[4]. Missimer[5] and Radebaugh[2,6] review the use of mixed gases in JT cryocoolers. Typically, higher boiling-point components, such as methane, ethane, and propane can be added to nitrogen to make the mixture behave more like a real gas over the entire temperature range. Enthalpy changes as much as 5 times that with pure nitrogen are possible with pressures of only 2.5 MPa. Such large enthalpy changes then lead to greatly increased efficiencies with the JT cryocooler at pressures that can be achieved in conventional compressors used for domestic or commercial refrigeration. The higher boiling point components must remain a liquid at the lowest temperature. In general, the freezing point of a mixture is less than that of the pure fluids, so temperatures of 77 K are possible with the nitrogen-hydrocarbon mixtures even though the hydrocarbons freeze in the range of 85 to 91 K as pure components. The presence of propane also increases the solubility of oil in the mixture at 77 K so that less care is needed in removing oil from the mixture when using an oil-lubricated compressor. Much research is currently underway pertaining to the solubility of oil in various mixtures and the freezing point of mixtures. Marquardt *et al.*[7] discuss the optimization of gas mixtures for a given temperature range and show how a mixed-gas JT

Figure 2. Open-cycle Joule-Thomson cryocooler for missle guidance.

cryocooler can be used for a cryogenic catheter only 3 mm in diameter. Such miniature systems could also be used for cooling infrared sensors.

2.1.2 Brayton cryocoolers

In Brayton cryocoolers (sometimes referred to as the reverse-Brayton cycle to distinguish it from a heat engine) cooling occurs as the expanding gas does work. Figure 1 shows a reciprocating expansion engine for this purpose, but an expansion turbine supported on gas bearings is more commonly used to give high reliability. According to the First Law of Thermodynamics the heat absorbed with an ideal gas in the Brayton cycle is equal to the work produced. This process is then more efficient than the JT cycle and it does not require as high a pressure ratio. The Brayton cycle is commonly used in large liquefaction plants. For small Brayton cryocoolers the challenge is fabricating miniature turboexpanders that maintain high expansion efficiency. Turbine diameters of about 6 mm on shafts of 3 mm diameter are typical in systems reviewed by McCormick *et al.*[8] for use in space applications of cooled infrared sensors. Turbine speeds of 2000 to 5000 rev/s are typical. Centrifugal compressors providing a pressure ratio of about 1.6 with a low-side pressure of 0.1 MPa are used with these systems. A similar system[9] to be used on the Hubble Space Telescope will provide 7 W of cooling at 70 K. The working fluid used in the turbo-Brayton cryocoolers is usually neon when operating above 35 K, but helium is required for lower temperatures.

An advantage of the Brayton cryocooler is the very low vibration associated with rotating parts in a system with turboexpanders and centrifugal compressors. This low vibration is often required with sensitive telescopes in satellite applications, such as with the Hubble telescope. The expansion engine provides for good efficiency over a wide temperature range, although not as high as some Stirling and pulse tube cryocoolers at temperatures above about 50 K. The low-pressure operation of the miniature Brayton systems requires relatively large and expensive heat exchangers.

2.2 Regenerative Cryocoolers

These cryocoolers operate with oscillating pressures and mass flows in the cold head. The oscillating pressure can be generated with a valveless compressor (pressure oscillator) as shown in Fig. 1 for the Stirling and pulse tube cryocoolers, or with valves that switch the cold head between a low and high pressure source, as shown for the Gifford-McMahon cryocooler. In the latter case a conventional compressor with inlet and outlet valves is used to generate the high- and low-pressure sources. An oil-lubricated compressor is usually used and oil removal equipment can be placed in the high-pressure line where there is no pressure oscillation. The use of valves greatly reduces the efficiency of the system. Pulse tube cryocoolers can use either source of pressure oscillations, even though Fig. 1 indicates the use of a valveless compressor. The valved compressors are modified air conditioning compressors, and they are used primarily for commercial applications where low cost is very important. The main heat exchanger in regenerative cycles is called a regenerator. In a regenerator, incoming hot gas transfers heat to the matrix of the regenerator, where the heat is stored for a half cycle in the heat capacity of the matrix. In the second half of the cycle the returning cold gas, flowing in the opposite direction through the same channel, absorbs heat from the matrix and returns the matrix to its original temperature before the cycle is repeated. Very high surface areas for enhanced heat transfer are easily achieved in regenerators through the use of stacked fine-mesh screen or packed spheres. Gifford-McMahon cryocoolers are seldom used in cooling infrared sensors because of their low efficiency and large size. Their input powers are usually 1 to 6 kW. Therefore, they will not be discussed further.

2.2.1 Stirling cryocoolers

The Stirling cycle, as invented and patented by Robert Stirling in 1815[10], was first used as a prime mover. In 1834 John Herschel proposed its use as a refrigerator in producing ice[11]. It was not until about 1861 that Alexander Kirk reduced the concept to practice[12]. Air was used as the working fluid in these early regenerative systems. Very little development of Stirling refrigerators occurred until 1946 when a Stirling engine at a Dutch company was run in reverse with a motor and was found to liquefy air on the cold tip[13]. The engine used helium as the working fluid, since earlier work at the company showed helium to give much improved performance to the engines. Stirling cryocoolers have been used for about the last

40 years in cooling infrared sensors for tactical military applications in such equipment as tanks and airplanes. They cannot provide the very fast cooldown times of JT cryocoolers, so they are not used on missiles for guidance. The long history of the Stirling cryocooler in cooling infrared equipment has resulted in many specifications being tailored to the geometry characteristics of the Stirling cryocooler. As a result, newer cryocoolers, like the pulse tube cryocooler, with different geometries are difficult to adapt to the geometry specifications.

A pressure oscillation by itself in a system would simply cause the temperature to oscillate and produce no refrigeration. In the Stirling cryocooler the second moving component, the displacer, is required to separate the heating and cooling effects by causing motion of the gas in the proper phase relationship with the pressure oscillation. When the displacer in Figure 1c is moved downward, the helium gas is displaced to the warm end of the system through the regenerator. The piston in the compressor then compresses the gas, and the heat of compression is removed by heat exchange with the ambient. Next the displacer is moved up to displace the gas through the regenerator to the cold end of the system. The piston then expands the gas, now located at the cold end, and the cooled gas absorbs heat from the system it is cooling before the displacer forces the gas back to the warm end through the regenerator. There is little pressure difference across the displacer (only enough to overcome the pressure drop in the regenerator) but there is a large temperature difference. Most actual Stirling cryocoolers have the regenerator inside the displacer instead of external as shown in Fig. 1c. The resulting single cylinder provides a convenient cold finger.

In practice, motion of the piston and the displacer are nearly sinusoidal. The correct phasing occurs when the volume variation in the cold expansion space leads the volume variation in the warm compression space by about 90°. With this condition the mass flow or volume flow through the regenerator is approximately in phase with the pressure. In analogy with AC electrical systems, real power flows only when current and voltage are in phase with each other. Without the displacer in the Stirling cycle the mass flow leads the pressure by 90º and no refrigeration occurs. Though the moving piston causes both compression and expansion of the gas, net power input is required to drive the system. The moving displacer reversibly extracts net work from the gas at the cold end and transmits it to the warm end where it contributes some to the compression work. In an ideal system, with isothermal compression and expansion and a perfect regenerator, the process is reversible. Thus, the coefficient of performance *COP* for the ideal Stirling refrigerator is the same as the Carnot *COP* given by

$$COP_{Carnot} = \frac{\dot{Q}_c}{\dot{W}_0} = \frac{T_c}{T_h - T_c}, \tag{1}$$

where $\dot{Q}_c$ is the net refrigeration power, $\dot{W}_0$ is the power input, T_c is the cold temperature, and T_h is the hot temperature. The occurrence of T_c in the denominator arises from the PV power (proportional to T_c) recovered by the expansion process and used to help with the compression. Practical cryocoolers have *COP* values that range from about 1 to 25% of the Carnot value.

Figure 3 shows the four sizes of Stirling cryocoolers that are currently used for military tactical applications. The refrigeration powers listed for each cooler are for a temperature of about 77 to 80 K, except the 1.75 W system, which is for a temperature of 67 K. Their specified minimum efficiencies range from about 3 to 6% of Carnot as the size increases. All of the coolers shown in Fig. 3 use linear drive motors with a dual-opposed arrangement to reduce vibration. The linear drive reduces side forces between the piston and the cylinder and the Mean-Time-To-Failure (MTTF) is at least 4000 hours. The displacer is driven pneumatically with the oscillating pressure in the system and because there is only one displacer it gives rise to considerable vibration. Efforts are currently underway[14] to increase the MTTF of these Stirling cryocoolers since they are the least reliable component in an infrared system. The development of cryocoolers for space applications has led to greatly improved reliabilities, and a MTTF of 10 years is now usually specified for these applications. The Stirling cooler was first used in these space applications after flexure bearings were developed for supporting the piston and displacers in their respective cylinders with little or no contact in a clearance gap of about 15 μm. Figure 4 shows two examples of flexure bearing geometries used in a compressor. The displacer would use the same type of flexure. These flexure-supported Stirling cryocoolers were initially very expensive, but advances in manufacturing have brought down the price to where these flexures are now being investigated for use in compressors in tactical

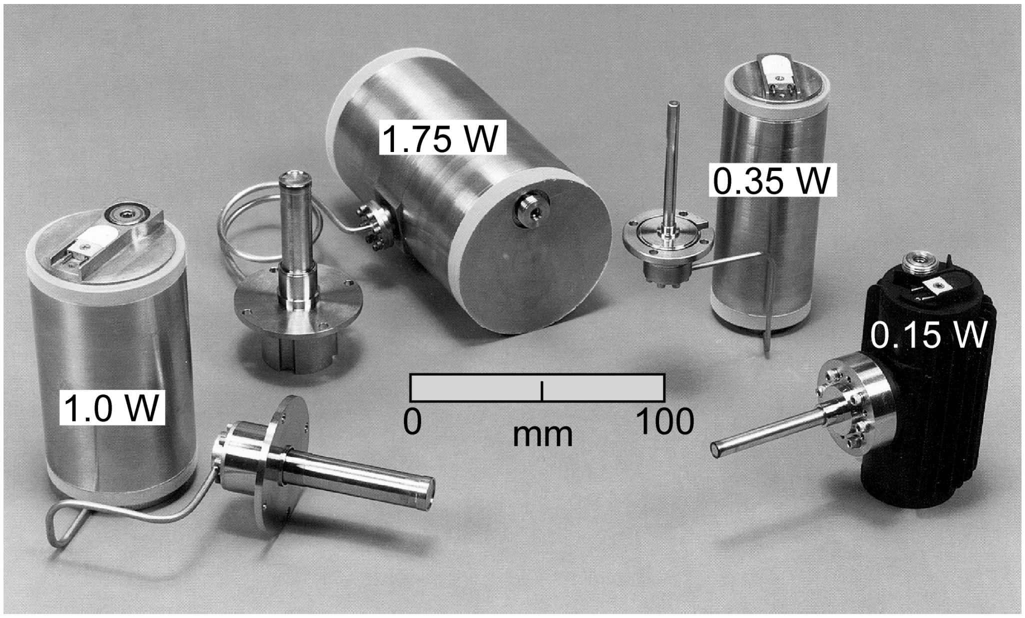

Figure 3. Four sizes of Stirling cryocoolers with dual-opposed linear compressors.

applications. Such compressors would also be useful for pulse tube cryocoolers, since they can use the same type of compressor.

2.2.2 Pulse tube cryocoolers

The moving displacer in the Stirling and Gifford-McMahon cryocoolers has several disadvantages. It is a source of vibration, has a limited lifetime, and contributes to axial heat conduction as well as to a shuttle heat loss. In the pulse tube cryocooler, shown in Figure 1d, the displacer is eliminated. The proper gas motion in phase with the pressure is achieved by the use of an orifice, along with a reservoir volume to store the gas during a half cycle. The reservoir volume is large enough that negligible pressure oscillation occurs in it during the oscillating flow. The oscillating flow through the orifice separates the heating and cooling effects just as the displacer does for the Stirling and Gifford-McMahon refrigerators. The orifice pulse tube refrigerator (OPTR) operates ideally with adiabatic compression and expansion in the pulse tube. Thus, for a given frequency there is a lower limit on the diameter of the pulse tube in order to maintain

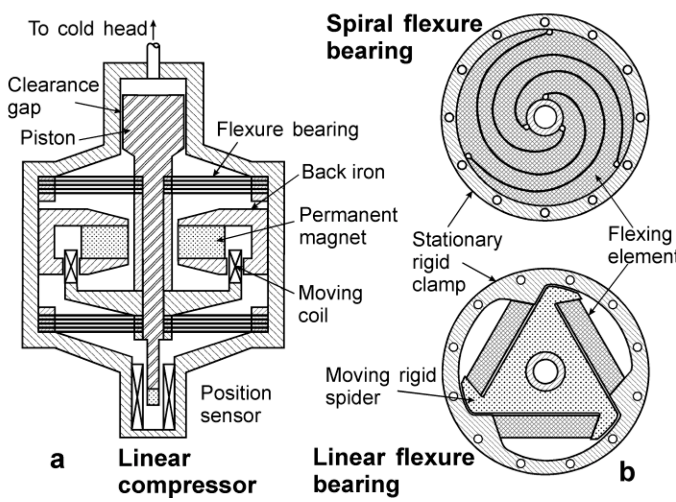

Figure 4. Schematic of (a) linear compressor with (b) two types of flexure bearings.

adiabatic processes. The four steps in the cycle are as follows. (1) The piston moves down to compress the gas (helium) in the pulse tube. (2) Because this heated, compressed gas is at a higher pressure than the average in the reservoir, it flows through the orifice into the reservoir and exchanges heat with the ambient through the heat exchanger at the warm end of the pulse tube. The flow stops when the pressure in the pulse tube is reduced to the average pressure. (3) The piston moves up and expands the gas adiabatically in the pulse tube. (4) This cold, low-pressure gas in the pulse tube is forced toward the cold end by the gas flow from the reservoir into the pulse tube through the orifice. As the cold gas flows through the heat exchanger at the cold end of the pulse tube it picks up heat from the object being cooled. The flow stops when the pressure in the pulse tube increases to the average pressure. The cycle then repeats. The function of the regenerator is the same as in the Stirling and Gifford-McMahon refrigerators in that it precools the incoming high-pressure gas before it reaches the cold end.

One function of the pulse tube is to insulate the processes at its two ends. That is, it must be large enough that gas flowing from the warm end traverses only part way through the pulse tube before flow is reversed. Likewise, flow in from the cold end never reaches the warm end. Gas in the middle portion of the pulse tube never leaves the pulse tube and forms a temperature gradient that insulates the two ends. Roughly speaking, the gas in the pulse tube is divided into three segments, with the middle segment acting like a displacer but consisting of gas rather than a solid material. For this gas plug to effectively insulate the two ends of the pulse tube, turbulence in the pulse tube must be minimized. Thus, flow straightening at the two ends is crucial to the successful operation of the pulse tube refrigerator. The pulse tube is the unique component in this refrigerator that appears not to have been used previously in any other system. It could not be any simpler from a mechanical standpoint. It is simply an open tube. But the thermohydrodynamics of the processes involved in it are extremely complex and still not well understood or modeled. The overall function of the pulse tube is to transmit hydrodynamic or acoustic power in an oscillating gas system from one end to the other across a temperature gradient with a minimum of power dissipation and entropy generation.

Pulse tube refrigerators were invented by Gifford and Longsworth[15] in the mid 1960s, but that type was different than what is shown in Fig. 1d and only reached a low temperature of 124 K. In 1984 Mikulin *et al.*[16] introduced the concept of an orifice to the original pulse tube concept and reached 105 K. In 1985 Radebaugh *et al.*[17] changed the location of the orifice to that shown in Fig. 1d and reached 60 K. Further improvements since then have led to a low temperature limit of about 20 K with one stage and 2 K with two stages. (See discussion in Reference 3.) There are three different geometries that have been used with pulse tube cryocoolers as shown in Fig. 5. The inline arrangement is the most efficient because it requires no void space at the cold end to reverse the flow direction nor does it introduce turbulence into the pulse tube from the flow reversal. The disadvantage is the possible awkwardness associated with having the cold

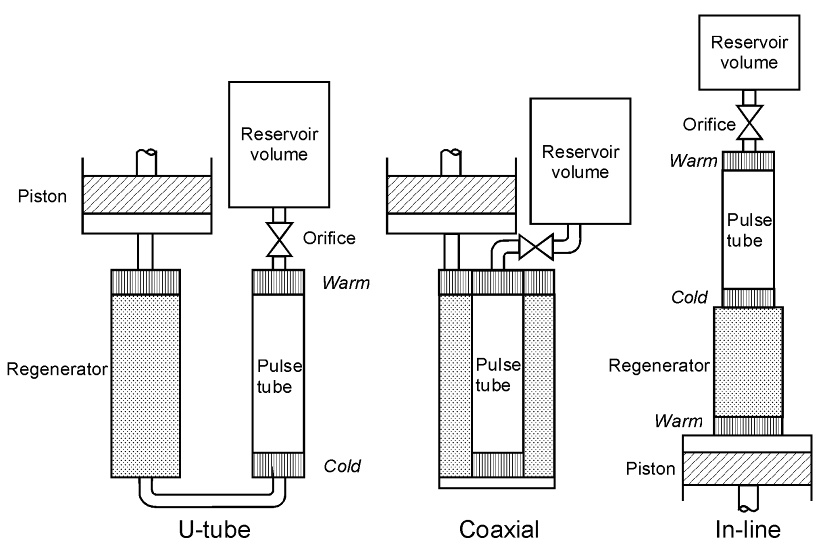

Figure 5. Three different geometries for pulse tube cryocoolers.

plate located between the two warm ends. The most compact arrangement and the one most like the geometry of the Stirling cryocooler is the coaxial arrangement. That geometry has the potential problem of a mismatch of temperature profiles in the regenerator and in the pulse tube that would lead to steady heat flow between the two components and a reduced efficiency. However, that problem has been minimized, and a coaxial geometry has been used as an oxygen liquefier for NASA with an efficiency of 17% of Carnot[18]. The coaxial geometry is the only geometry that could possibly meet the geometry specifications of the Standard Advanced Dewar Assembly (SADA) for second-generation thermal imaging systems[14, 19] of the military. The absence of a moving displacer in pulse tube cryocoolers gives them many potential advantages over Stirling cryocolers for the cooling of infrared sensors. Early pulse tube cryocoolers were not nearly as efficient as Stirling cryocoolers, but advances in the last ten years have brought pulse tube refrigerators to the point of being the most efficient of all cryoolers. Some details of this rapid progress are given in the following section.

3. ADVANCES IN PULSE TUBE CRYOCOOLERS

3.1. Phase Shift Mechanisms

In regenerative cryocoolers the optimum phase relationship between the pressure and the mass (or volume) flow is to have the two in phase with each other near the center of the regenerator. Because of the gas volume in the regenerator the mass flow at the warm end of the regenerator will lead the pressure, but the flow at the cold end will lag the pressure. With such a phase relationship the magnitude of the average mass flow rate through the regenerator for a given PV power is minimized. Because the regenerator losses (such as pressure drop and imperfect heat transfer) depend mostly on the magnitude of the mass flow rate, the regenerator losses are minimized and the system efficiency is maximized. In a Stirling cryocooler, where the displacer is driven, the optimum phase angle can always be achieved. In the orifice pulse tube refrigerator the mass flow rate and the pressure are in phase at the orifice because of the purely resistive nature of the flow impedance in an orifice. In practice the orifice can be any resistive flow element such as an orifice, a needle valve (for adjustment purposes), a capillary, or a porous plug. In all cases the flow through the element is in phase with the dynamic pressure (same as the pressure drop because the pressure in the reservoir is constant). Because of the gas volume in the pulse tube the conservation of mass dictates that the mass flow at the cold end of the pulse tube and regenerator will lead the mass flow at the warm end of the pulse tube (typically about 30° with an optimum pulse tube volume). Consequently, the mass flow at the cold end also leads the pressure instead of lagging the pressure at that location for the minimum regenerator loss. The pressure does not change phase or amplitude through a typical pulse tube, unless frequencies much above 60 Hz are used. The mass flow at the warm end of the regenerator then greatly leads the pressure (perhaps by as much as 60°), which gives rise to a large amplitude of mass flow and causes large regenerator losses for a given PV power flow. Thus, early orifice pulse tube refrigerators were not as efficient as Stirling cryocoolers, and they required a compressor with a larger swept volume. Then mechanisms were found to shift the phase without the need for a moving part.

3.1.1. Double inlet (secondary orifice)

In 1990 Zhu, Wu, and Chen[20] introduced the concept of a secondary orifice to the OPTR in which the secondary orifice allows a small fraction (about 10%) of the gas to travel directly between the compressor and the warm end of the pulse tube, thereby bypassing the regenerator. They called this the double-inlet pulse tube refrigerator. This bypass flow is used to compress and expand the portion of the gas in the warm end of the pulse tube that always remains at the warm temperature. The bypass flow reduces the flow through the regenerator, thereby reducing the regenerator loss. The flow through the secondary orifice is in phase with the pressure drop across the regenerator, which, in turn, is approximately in phase with the flow through the regenerator, averaged over its length. Since the flow usually leads the pressure, so too will the flow through the secondary. This secondary flow then forces the flow at the warm end of the pulse tube to lag the pressure, since the sum of the flows must be in phase with the pressure at the primary orifice. The location of the secondary orifice is shown in Fig. 6, along with that of an inertance tube described in the next section.

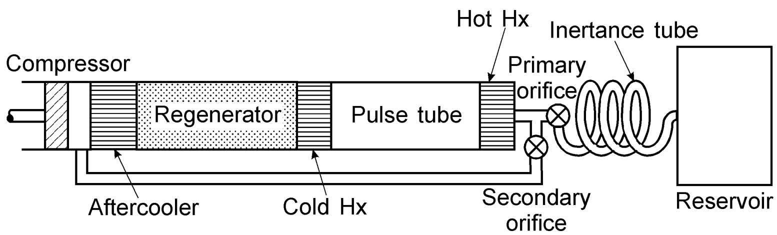

Figure 6. Schematic of pulse tube cryocooler with secondary orifice (double inlet) and inertance tube.

The double-inlet pulse tube refrigerator led to increased efficiencies, particularly at high frequencies where the regenerator losses would be quite high in a simple OPTR. The secondary orifice was incorporated in the mini pulse tube described by Chan *et al.*[21]. This refrigerator produced 0.5 W of cooling at 80 K with only 17 W of input power. About 30 of these mini pulse tube refrigerators have been built and are scheduled for a variety of space missions, mostly for cooling infrared detectors. The secondary orifice has been used on a majority of small pulse tube refrigerators built since about 1991.

3.1.2. DC flow or streaming

Though the introduction of the secondary orifice usually led to increased efficiencies compared to the OPTR, it also introduced a problem. Performance of the double inlet pulse tube refrigerator was not always reproducible, and sometimes the cold end temperature would slowly oscillate by several degrees with periods of several minutes or more. Researchers began attributing this erratic behavior to DC flow that can occur around the loop formed by the regenerator, pulse tube, and secondary orifice. Asymmetric flow impedance in the secondary can cause such a DC flow. Even small DC flow carries a large enthalpy flow from the warm to the cold end because of the large temperature difference at the two ends. In 1997 Gedeon[22] showed that the acoustic power flowing from the warm to the cold end of the regenerator brings about an intrinsic driving force for DC flow or streaming in the same direction as the acoustic power flow. As a result, an asymmetric secondary is required to cancel the intrinsic tendency for this DC flow. In the author's lab the use of a needle valve for the secondary with the needle pointing toward the warm end of the pulse tube resulted in a no-load temperature on a small pulse tube refrigerator of about 35 K. When the needle valve was reversed, the no-load temperature increased to about 50 K. A tapered tube, also known as a jet pump, has also been used to cancel the DC flow[23].

Direct measurements of this small DC flow superimposed on the AC flow would be nearly impossible and have never been attempted. Instead, it is customary to measure the temperature profile on the outside of the regenerator and compare that with the calculated profile or the measured profile when the secondary is closed. Except for very low temperatures the normalized temperature at the midpoint on the regenerator is about 50 to 55% of the total temperature difference. DC flow from the warm end of the regenerator increases the midpoint temperature, whereas flow in the opposite direction reduces the midpoint temperature.

3.1.3. Inertance tube

The conservation of momentum equation for the working fluid is

$$-\frac{\partial \boldsymbol{P}}{\partial x} = \frac{f_r |\dot{m}| \dot{\boldsymbol{m}}}{2 r_h \rho_0 A_g^2} + \frac{\partial}{\partial t}\left(\frac{\dot{\boldsymbol{m}}}{A_g}\right) + \frac{\partial}{\partial x}\left\{\frac{1}{\rho_0}\left(\frac{\dot{\boldsymbol{m}}}{A_g}\right)^2\right\}, \tag{2}$$

and the conservation of mass equation is

$$-\frac{\partial}{\partial x}\left(\frac{\dot{\boldsymbol{m}}}{A_g}\right) = \frac{\partial \dot{\boldsymbol{\rho}}}{\partial t} = \frac{\dot{\boldsymbol{P}}}{R T_0}, \tag{3}$$

where the bold variables represent time-varying complex variables or phasor quantities, $\dot{m}$ is the mass flow rate (positive for flow from compressor to reservoir), x is the coordinate in the flow direction from compressor to reservoir, P is the pressure, f_r is the Darcy friction factor, r_h is the hydraulic radius, ρ_0 is the density at the average temperature and pressure, A_g is the cross-sectional area of the gas perpendicular to the flow direction, R is the gas constant on a mass basis, T is the temperature, and t is the time. The ideal-gas equation of state was used for the last term in Eq. (3). Equations (2) and (3) show phase relationships between flow and pressure. The first term on the right hand side of Eq. (2) represents the flow friction or flow resistance. The last term is important where A_g changes rapidly. The second term on the right hand side of Eq. (2) was usually neglected in the early work with OPTRs since frequencies were low (<60 Hz) and mass flow rates were low. In those cases the pressure drop was in phase with the mass flow. However, at higher frequencies or higher flow rates the second term is no longer negligible in the pulse tube or in other tubes used for the complete system. This second term gives rise to a component of the pressure drop that is in phase with the acceleration of the mass, which for a sinusoidally varying mass flow leads the mass flow by 90°. It represents an inertance effect and is brought about because of the inertia of the oscillating gas. It is analogous to an inductive effect in electrical systems. When combined with the resistive term, the pressure leads the mass flow by something less than 90°. As discussed earlier, this phase shifting at the warm end of the pulse tube is desirable to reduce the magnitude of the flow in the regenerator.

Equation (3) shows that any element that has a finite volume causes a change in mass flow toward the compressor that leads the pressure by 90°, which is opposite to the desired phase shift. Such a phase shift is known as a compliance effect and is analogous to a capacitance effect in electrical systems. The overall change in phase angle from one end to the other in any element is determined by solving both Eqs. (2) and (3). The beneficial phase shift caused by an inertance effect within the pulse tube was first observed in 1996 by Godshalk *et al.*[24] in an OPTR operating at 350 Hz. The inertance effect can be enhanced further by using a long, narrow tube between the pulse tube and the reservoir[2,25,26], as shown in Fig. 6. The primary orifice in Fig. 6 can actually be removed and the entire flow impedance incorporated into the inertance tube. In a pulse tube providing 19 W at 90 K, Marquardt and Radebaugh[18] increased the phase shift further by using an inertance tube with two diameters to provide a phase shift of 43°. The length of both tubes combined was 4.3 m, with the small-diameter tube next to the pulse tube. In much smaller pulse tubes the phase shift is so small that it is of little use, but in much larger pulse tubes the phase shift can be larger than optimum unless the geometry of the inertance tube is adjusted to reduce the phase shift. In small pulse tubes both the secondary orifice and the inertance tube need to be used together to give a desirable phase shift. The advantage of using only the inertance tube is that there is no possibility of DC flow.

3.2. Efficiency of Pulse Tube Cryocoolers

3.2.1. Intrinsic OPTR efficiency

In the ideal OPTR the only loss is the irreversible expansion through the orifice. The irreversible entropy generation there is a result of lost work that otherwise could have been recovered and used to help with the compression. All other components are assumed to be perfect, and the working fluid is assumed to be an ideal gas. The *COP* for this ideal OPTR is given by[27]

$$COP_{ideal} = \frac{\dot{Q}_c}{\dot{W}_0} = \frac{\langle P_d \dot{V}_c \rangle}{\langle P_d \dot{V}_h \rangle} = \frac{T_c}{T_h}, \tag{4}$$

where P_d is the dynamic pressure, $\dot{V}$ is the volume flow rate, and the net refrigeration power is simply taken as the acoustic power at the cold end. The ⟨⟩ symbols indicate a time-averaged quantity. The acoustic power at the hot end of the regenerator is simply the PV power of the compressor. Because the regenerator is assumed to be perfect, the acoustic power varies along its length in accordance with the specific volume, which is proportional to temperature for an ideal gas. The maximum *COP* from Eq. (4) is 1.0, but only when the cold temperature becomes equal to the hot temperature. A comparison of the *COP* from Eq. (4) with the Carnot *COP* from Eq. (1) shows that the only difference is the presence of the T_c term in the denominator of Eq. (1). That term represented the work reversibly recovered at the low temperature and used to help in the compression. The Carnot efficiency of the ideal OPTR is given by

$$\eta_{ideal} = \frac{COP_{ideal}}{COP_{Carnot}} = \frac{T_h - T_c}{T_h}. \quad (5)$$

For T_h = 300 K and T_c = 75 K, η_{ideal} = 0.75. Since practical pulse tube refrigerators have efficiencies less than about 20% of Carnot, the intrinsic loss is dominated by other practical losses when operating at this low temperature. However, for T_c = 250 K, η_{ideal} = 0.17. In that case the lost power at the orifice is a much larger fraction of the total input power. Thus, the OPTR cannot compete with the vapor-compression refrigerator for near-ambient operation. It is useful only for much lower temperatures, especially cryogenic temperatures, unless the acoustic power flow at the warm end of the pulse tube is recovered.

3.2.2. Efficiencies of real pulse tube cryocoolers

Figure 7 shows a comparison of the efficiency of actual pulse tube refrigerators that have achieved high efficiencies. The efficiencies reported here refer to the input electrical power to the compressor. In a few cases the number 85 associated with a data point means that the efficiency was based on compressor PV power that was divided by 0.85 to obtain the electrical input power if an 85% efficient compressor had been used. Such compressor efficiencies are typical of well-designed units. The majority of pulse tube refrigerators reported in the literature have not achieved efficiencies anywhere near these values. Careful attention to details in the design of these high efficiency refrigerators is required and expensive experimental optimization is often required even after the most careful computer modeling and optimizations are performed. In most cases these detailed designs remain proprietary information. Shown for comparison are data for recent, high efficiency Stirling, Gifford-McMahon, Brayton, and mixed-refrigerant Joule-Thomson refrigerators, all operating at temperatures near 80 K. This graph shows a general trend in all refrigerators for increased efficiency as the size increases. The graph also indicates that pulse tube refrigerators have equaled or exceeded the efficiency of the best Stirling refrigerators. As a result, pulse tube refrigerators have now become the most efficient cryocoolers for a given size. Efficiencies as high as 24% of Carnot have now been achieved with pulse tube cryocoolers[28]. As expected, the use of a valved compressor reduces the efficiency of the pulse tube refrigerator to about that of Gifford-McMahon refrigerators.

The minimum efficiencies required for SADA applications are also shown in Fig. 7, but they are much less than what has been achieved in many pulse tube cryocoolers. However, most actual Stirling cryocoolers for this application also have considerably higher efficiencies. The lower cost compressors for

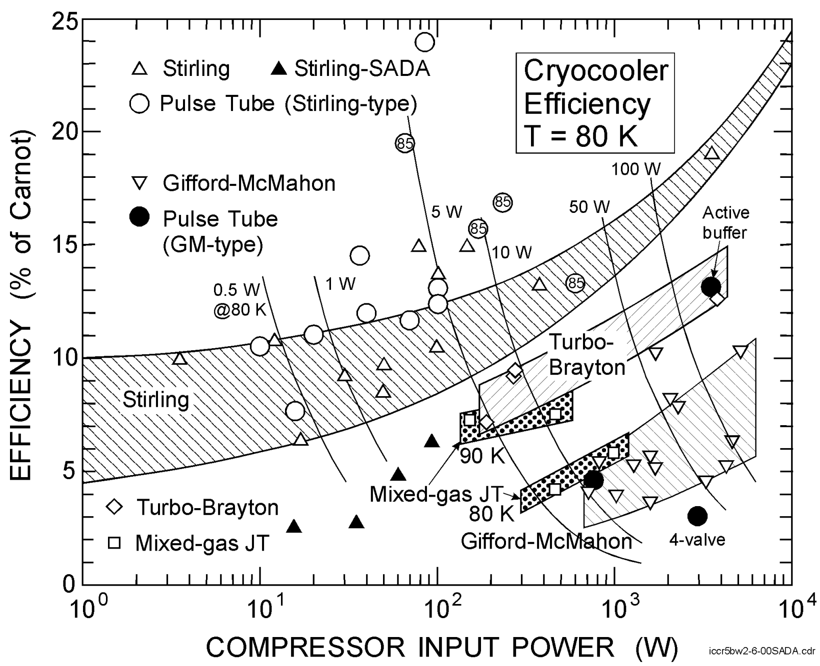

Figure 7. Efficiencies of various types of cryocoolers at 80 K.

the tactical military application are usually only about 65% efficient compared with the 85% typical of compressors for most space cryocoolers. With such compressors most of the Stirling-type pulse tube efficiencies would be reduced from that shown in Fig. 7. However, the data point at 40 W of input power at an efficiency of 12% of Carnot was a pulse tube cryocooler driven with a linear compressor intended for use with a Stirling cryocooler that provides at least 1.75 W at 67 K. The SADA requirement for the maximum input power is 94 W. With a pulse tube cold head the input power was 40 W when providing 1.75 W at 80 K, which is the same as the input power to the system when the original Stirling coldhead was in place[29]. This pulse tube had a U-tube geometry that would not fit inside the envelope specified for the SADA applications.

The earliest pulse tube refrigerator to achieve these high efficiencies was the large NIST pulse tube in 1991 that achieved 31 W at 80 K with 602 W input PV power at 316 K (13% of Carnot assuming an 85% efficient compressor). Within about a year the mini pulse tube refrigerator discussed earlier achieved about 8% of Carnot[21]. Most of the other pulse tube refrigerators with high efficiencies have been developed in the last few years for space applications with funding provided either by NASA or by the U.S. Air Force. The system with 17% efficiency at 222 W of input power is the NIST oxygen liquefier[18] mentioned previously that used the coaxial arrangement. Figure 8 shows this pulse tube cryocooler. Figure 9 shows one of the latest space-qualified pulse tube cryocoolers designed for cooling infrared sensors on the Integrated Multispectral Atmospheric Sounder (IMAS)[30]. It provides 1.0 W cooling at 55 K and 2.5 W at 80 K with only 51 W of input power to the compressor[31] to give an efficiency of 13.5% of Carnot. It uses the latest technology in flexure-bearing compressors to reduce the size and mass of the compressor. Total mass of the compressor and pulse tube cold head is only 3.2 kg. It uses an inline arrangement for the regenerator and pulse tube.

One of the few disadvantages of pulse tube cryocoolers is the potential for gravitationally induced convective instabilities inside the pulse tube whenever the cold end of the pulse tube is raised above the warm end. The effect can be particularly pronounced in the off state, but the oscillating flow in the on state prevents the instability except for pulse tube diameters greater than about 10 mm. Very few measurements have been made of this instability in the on state. Two measurements in our laboratory, one with a 9-mm diameter pulse tube and the other with a 19-mm diameter pulse tube showed no orientation dependence for the first and about a 15 K temperature increase for the second. We expect that even for the 1.75 W SADA application the pulse tube diameter will be less than 10 mm, so this potential problem may not exist for these infrared applications.

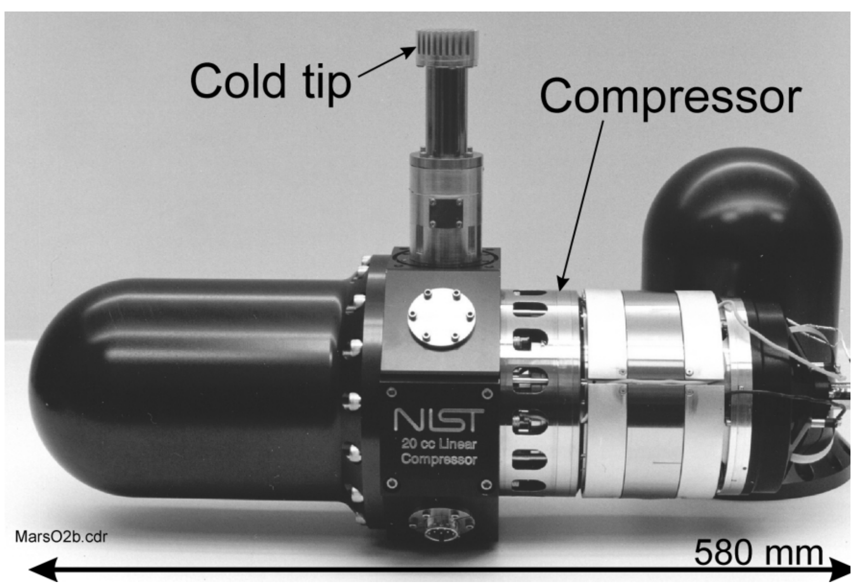

Figure 8. Photograph of a coaxial pulse tube cryocooler for studies of liquefaction of oxygen on Mars.

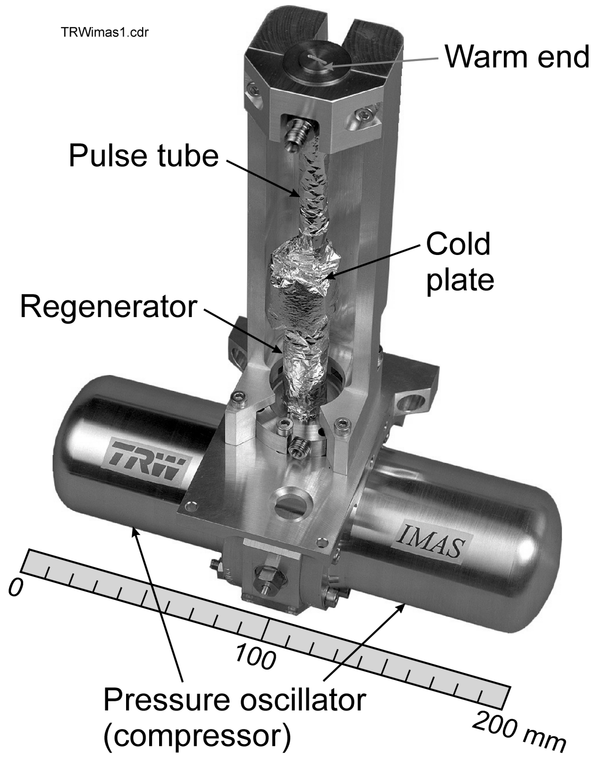

Figure 9. Photograph of an inline pulse tube refrigerator for cooling infrared sensors in space.

4. COOLING INFRARED DETECTORS FOR TACTICAL APPLICATIONS

4.1. Requirements for the Standard Advanced Dewar Assembly (SADA)

Table 2 lists the performance and geometry requirements for cryocoolers used with second-generation thermal imaging systems[14]. As discussed in the previous section the efficiency of many current pulse tube refrigerators greatly exceeds the SADA requirements. The four remaining challenges in the use of pulse tubes for this application are (1) the geometry of the cold finger, (2) the operation at any orientation, (3) the cool-down time, and (4) the additional mass and volume due to the reservoir. The many other SADA requirements not listed in Table 2 should affect the pulse tube cryocooler no differently than they affect the Stirling cryocooler. In fact, the vibration levels with the pulse tube cryocooler should be significantly less

Table 2. Performance and geometry requirements of cryocoolers for second-generation thermal imaging systems.

Requirement \ System	0.15 W	0.35 W	1.0 W	1.75 W
Cooling Capacity @ 23 °C Ambient	0.15 W @ 77 K	0.35 W @ 80 K	1.0 W @ 77 K	1.75 W @ 67 K
Cool-down Time to 80 K	2.5 min w/125 J	10 min w/250 J	13 min w/1440 J	6.5 min w/1200 J
Input Power (max)	17 W	35 W	60 W	94 W
Mass (max)	0.45 kg	1.14 kg	1.91 kg	3.41 kg
Reliability, Min MTTF	4000 hr	4000 hr	4000 hr	4000 hr
Cold Finger Diameter	6.6 mm	5.0 mm	13.7 mm	13.7 mm
Cold Finger Length	57 mm	62 mm	59 mm	59 mm

than those with the Stirling cryocooler because of the lack of moving parts in the cold head. With the SADAs the sleeve for the cryocooler cold finger is built into the dewar. For a Stirling cold head the displacer fits inside this sleeve as shown in Fig. 10a. Figure 10b shows how a coaxial pulse tube would fit into the same sleeve.

4.2. Adapting Pulse Tube Cryocoolers to SADA Requirements

The optimum cross-sectional area of the regenerator in any cryocooler will be proportional to the refrigeration power to a first approximation, and the length as well as the mesh size of the screen regenerator will not change. This scaling law assumes all losses are proportional to the cross sectional area for a fixed flow velocity. This assumption is reasonably good until radiation loss begins to dominate. The cross-sectional area of the pulse tube can also be scaled with the refrigeration power until at some small size the thermal penetration depth in the gas is no longer small compared with the tube radius. At 60 Hz the thermal penetration depth in helium at 300 K is 0.20 mm. We have found that for a pulse tube radius less than about 2.0 mm performance deteriorates quickly because of excessive heat transfer between the gas and the wall. With this size of system the radiation loss also begins to become quite important since it scales with the surface area instead of the cross-sectional area. Most published data on the pulse tube cryocoolers with high efficiencies do not give dimensional data on the regenerators and pulse tubes. However, data from two NIST pulse tube cryocoolers with high efficiencies is available and has been published. The first[18] is the pulse tube oxygen liquefier that produced 15 W at 80 K using a coaxial geometry, and the second[32] is an inline pulse tube cryocooler that produced 2.5 W of cooling at 80 K using the linear compressor from the tactical Stirling cryocooler intended to produce 1.75 W at 80 K. More recent unpublished data with the same compressor and regenerator #4, but with a larger pulse tube (5.33 mm ID x 45.7 mm long) yielded 3.4 W of cooling at 80 K. The compressor PV power at this high refrigeration power was about 100 W and is greater than the SADA specifications. Nevertheless, this data along with the data from the oxygen liquefier can be used to determine the coefficients in the scaling of cross-sectional areas of the regenerators and pulse tubes.

For the regenerator the ratio of inside cross-sectional area to net refrigeration power at 80 K is Ar_q = 0.32 cm^2/W for the 15 W system and 0.28 cm^2/W for the 2.5 W system. To be conservative the higher value will be used for scaling to smaller sizes. The regenerator length was 50 mm for the larger one and 40 mm for the smaller one. Performance of the larger system with a 40-mm long regenerator was almost the same. For the pulse tube the ratios are Ap_q = 0.084 cm^2/W for the large system and 0.057 cm^2/W for the small system. Again, the larger value will be used to be conservative regarding a fit inside the SADA sleeve. The pulse tube lengths were 70 mm for the larger system and 46 mm for the smaller system. Ideally the pulse tube length in a coaxial system should be somewhat longer than the regenerator to match the temperature profiles closely. An extra 10-mm length in the pulse tube compared with the regenerator can be located at the warm end and outside the SADA sleeve. Sleeve lengths for the four SADA systems are in the range of 55 to 60 mm with about 10 mm at the warm end with no temperature gradient.

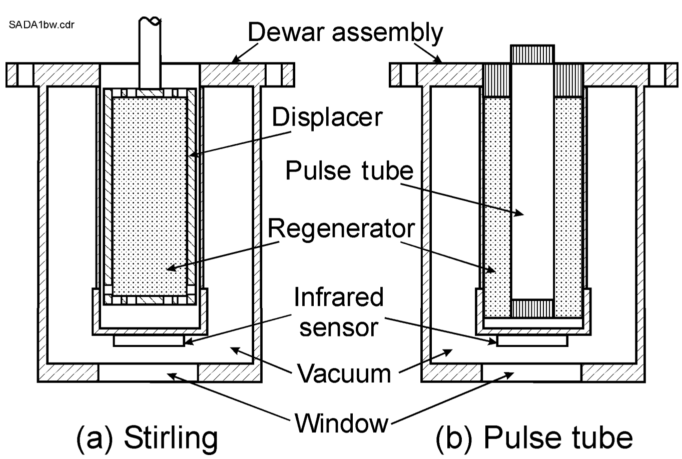

Figure 10. Integration of cryocooler with standard dewar assembly.

With the specific areas given above for the regenerator and the pulse tube along with a pulse tube wall thickness of 0.15 mm and a regenerator wall thickness of 0.25 mm, we obtain the diameters as given in Table 3. For the two smaller systems the pulse tube diameters given in the parentheses indicate the diameters when using the scaling relationship. The 3.0 mm diameter is given next as the minimum allowed diameter to prevent excessive heat transfer with the wall. Regenerator areas were increased by 20% for the 0.15 W system and 10% for the 0.35 W system to allow for degradation of net refrigeration at small sizes. The regenerator areas in parentheses are the values before the 205 and 10% were added. As this table shows, the cold fingers predicted from simple scaling laws applied to previously tested pulse tube cryocoolers have diameters smaller than the SADA requirements, except for the 0.35 W cooler. It may still be possible to meet the requirements for the 0.35 W cooler, but more careful optimization and experimentation would be required. The scaling law used here was for 80 K, but the 1.75 W cooler must provide that cooling at 67 K. Thus more PV power will be required and may increase the diameter of the cold finger some, but it should still be possible to keep it less than 13.7 mm. Because the pulse tube diameter even for the largest cooler is significantly less than 10 mm in diameter, there should be no orientation dependence during operation of any of the four pulse tube coolers. Cool-down times for pulse tube cryocoolers should be quite similar to that of an equivalent Stirling cryocooler because the size and mass of the cold finger is about the same for the two systems. Table 3 also lists the approximate volumes needed for the reservoirs of the various pulse tube coolers. This volume is taken as 50 times the pulse tube volume. Often this reservoir volume is placed internal to the compressor and requires no additional volume and a very small additional mass. That procedure requires that the compressor be designed specifically to accommodate the reservoir. It could also be place external to the compressor as an annular sleeve[28]. An external reservoir could also be made part of the warm end of the cold head, including the use of fins for heat rejection. This extra volume is not significantly more than that required for the pneumatic drive of the displacer in Stirling cryocoolers. Details of the envelope specification for the warm end of the cold head would need to be examined in detail to be able to best incorporate the reservoir volume.

5. CONCLUSIONS

Many advances in pulse tube refrigerators have occurred in the last few years, particularly in methods to increase the efficiency. Several high efficiency pulse tube cryocoolers have been developed for space applications, mostly for cooling infrared detectors. Efficiencies in the range of 10 to 24% of Carnot at 80 K have been achieved in small pulse tube cryocoolers with input powers of 10 to 100 W. Such efficiencies are much higher than the 2.5 to 6.4% efficiencies required of the cryocoolers for the second-generation thermal imaging systems in the Standard Advanced Dewar Assembly (SADA) specifications. With such high efficiencies it should then be possible to make pulse tube refrigerators with coaxial geometries for the pulse tube and regenerator that have small enough diameters and lengths for the cold finger to fit SADA systems. Estimated diameters were determined from scaling laws applied to somewhat larger systems that were very efficient and well characterized. The 1.0 W and 1.75 W coolers should be relatively easy to retrofit. The 0.35 W cooler will require careful optimization and experimentation to develop a pulse tube cooler with such a small diameter cold finger. The 0.15 W cooler with maximum input power of 17 W is

Table 3. Estimated geometry of cold finger for coaxial pulse tube cryocooler.

Geometry \ System	0.15 W	0.35 W	1.0 W	1.75 W
Pulse Tube Area (cm^2)	0.0126	0.0294	0.084	0.147
Pulse Tube ID (mm)	(1.27) 3.0	(1.93) 3.0	3.27	4.33
Pulse Tube OD (mm)	3.3	3.3	3.57	4.63
Regenerator Area (cm^2)	(0.048) 0.058	(0.112) 0.123	0.32	0.56
Regenerator ID (mm)	4.27	5.15	7.31	9.63
Regenerator OD (mm)	4.77	5.65	7.81	10.03
Reservoir Volume (cm^3)	(3.8) 21	(3.8) 21	25	44
Required Cold Finger OD (mm)	6.6	5.0	13.7	13.7
Required Cold Finger Length (mm)	56.8	61.6	58.5	58.5

near the lower limit of size for efficient pulse tube cryocoolers. Fortunately, the cold finger diameter is not particularly small for this cooler, but the challenge on this system is to maintain high efficiency with such a small compressor. The small pulse tubes in these systems should not experience any orientation dependence. Several possible locations for the reservoir volume were discussed.

ACKNOWLEDGEMENTS

I appreciate the valuable discussions with W. E. Salazar and R. M. Rawlings regarding the requirements and characteristics of linear Stirling cryocoolers in the cooling of infrared detectors. I also wish to thank R. M. Rawlings for the loan of two linear Stirling compressors for our use in the development of small pulse tube cryocoolers.

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EXHIBIT B

Status of Programs for the DoD Family of Linear Drive Cryogenic Coolers for Weapon Systems

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ABSTRACT

The Standard Advanced Dewar Assembly (SADA) is the critical module in the Department of Defense (DOD) standardization effort of second-generation thermal imaging systems. DOD has established a family of SADAs to address high performance (SADA I), mid-to-high performance (SADA II), and compact class (SADA III) systems. SADAs consist of the Infrared Focal Plane Array (IRFPA), Dewar, Command & Control Electronics (C&CE), and the cryogenic coolers. SADAs are used in weapons systems such as Comanche, the M1 Abrams tank, the M2 Bradley fighting vehicle, and the Javelin CLU.

The linear drive cryocoolers maintain the Infrared Focal Plane Arrays (IRFPAs) at the desired operating temperature. Stirling linear drive cryocoolers are being used in place of Stirling rotary coolers. DOD has defined a family of tactical linear drive coolers in support of the family of SADAs. These coolers are required to have low input power, a quick cool-down time, low vibration output, low audible noise, and higher reliability. This paper (1) outlines the characteristics of each cooler, (2) presents the status and results of qualification tests, and (3) presents the status and test results of efforts to increase cryocooler reliability. Flexure-spring designs of the 0.15 watt and 1.0 watt coolers are currently in reliability growth testing.

INTRODUCTION

The US Department of Defense (DoD) has chartered a strategy to standardize second generation infrared (IR) components throughout the services. A family of second-generation (2^{nd} Gen.) infrared-imaging critical components called the Standard Advanced Dewar Assemblies (SADA's) has been developed to support this strategy. SADA I is designed to address requirements for high performance systems, SADA II for mid-to-high performance, and SADA III for compact class systems. SADAs consist of the Infrared Focal Plane Array (IRFPA), dewar, Command & Control Electronics (C&CE), and the cryogenic cooler.

The US Army CECOM Night Vision and Electronics Sensors Directorate (NVESD) has developed a family of Stirling cycle linear drive coolers, shown in Fig. 1, in support of this standard-

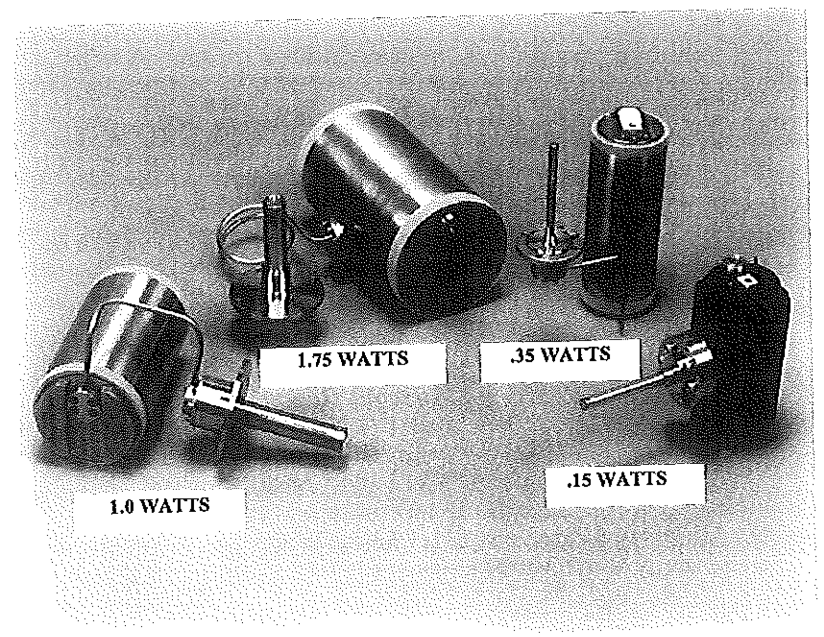

Figure 1. Family of linear drive coolers.

ization effort.[1] These coolers address the shortcomings of rotary coolers such as low reliability, poor shelf life, multi-axes vibration & torque, excessive acoustic noise, and poor temperature stability of the detector array. This paper highlights the latest developments and results involving US Army programs for linear drive coolers. Table 1 highlights the key parameters of the family of coolers.

Table 1. Key Parameters for the Family of Linear Drive Coolers (LDC's)

Requirements	0.15 watt	0.35 watt	1.0 watt	1.75 watt
Cooling Capacity @ 23C in any orientation	0.15 watt @ 77K	0.35 watt @ 80K	1.0 watt @ 77K	1.75 watt @ 67K
Cool-down time to 80K @ 23C (max)	2.5 minutes w/125 Joules	10 minutes w/250 Joules	13 minutes w/1440 Joules	6.5 minutes w/1200 joules
Input power (max)	17 W	35 W	60W	94W
Temperature regulation	+/- 0.5K	+/- 0.5 K	+/- 0.5 K	+/- 0.5 K
Operating Voltage	10.8 VAC	17-32 Vdc	17-32 Vdc	24-32 Vdc
Vibration Output (max)	0.25 lbf	0.5 lbf	0.5 lbf/ 0.75 lbf in Dewar axis	0.5 lbf
Weight (max)	1.0 lbs	2.5 lbs	4.2 lbs	7.5 lbs
Reliability (minimum Mean Time to Failure)	4000 MTTF	4000 MTTF	4000 MTTF	4000 MTTF
Electromagnetic compatibility	MIL-STD-461 Modified	MIL-STD-461 Modified	MIL-STD-461 Modified	MIL-STD-461 Modified
Shelf Life	10 years	10 years	10 years	10 years
Operating Environment	-32C to +70C	- 54C to +71C	- 54C to +71C	- 54C to +71C

Table 2. List of Qualification Tests

QUALIFICATION TESTS	DESCRIPTION
• LEAK RATE *	Ensure 10-year shelf life
• BASELINE PERFORMANCE TESTING * • Verify critical performance requirements at environmental temperatures of 23C, +71C and -54C (-32C for 0.15W)	• Key Performance Parameters • Cool-down time • Input Power • Cooling Capacity • Temperature control
• AUDIBLE NOISE *	Test to ensure compliance to required sound levels
• VIBRATION OUTPUT LEVELS *	Measure force generated by the cooler along principal axes
• HIGH TEMPERATURE *	Test to demonstrate operation of coolers after +71C storage temperature
• LOW TEMPERATURE *	Test to demonstrate operation of coolers after −62C storage temperature
• TEMPERATURE SHOCK *	Test to demonstrate coolers survive sudden temperature changes from −62C to 71C
• MECHANICAL SHOCK	Test to demonstrate coolers are operational while being subjected to high intensity shocks in all axes
• MECHANICAL VIBRATION	Test to demonstrate coolers are operational while being subjected to vibration (specified by platform) in all axes
• ELECTROMAGNETIC RADIATION	Test to ensure compliance to radiated emissions and susceptibility requirements
• RELIABILITY TEST (4000 HOURS MEAN TIME TO FAILURE) *	Coolers log 4,000 operating hours while undergoing 3-day temperature cycling from –32C to +52C
• PHYSICAL CONFIGURATION AUDIT *	Measure size, weight Verify interface with FPA/Dewar assembly

* NVESD In-house Testing Capability

QUALIFICATION REQUIREMENTS FOR CRYOCOOLERS

SADAs and linear drive coolers are products that require qualification prior to first delivery. These components are qualified once they pass through a series of tests approved by NVESD and the procurement activity. The government or the cryocooler manufacturer may perform these tests. The government approves all test procedures, equipment, and test facilities prior to testing. Some of the weapon systems supported by this qualification effort include the Army's Second Generation Forward Looking Infrared (FLIR) Horizontal Technology Integration (HTI), Comanche, Apache, Javelin, Improved TOW Acquisition Sensor, and Long Range Advanced Scout Sensor Suite (LRAS3). The tests in Table 2 are part of the qualification effort for linear drive coolers.

0.15-WATT LINEAR DRIVE COOLERS

The 0.15-watt linear drive cooler was developed for second-generation FLIR man-portable applications. The 0.15-watt cooler from DRS Infrared Technologies (formerly Texas Instruments) was originally qualified in 1997 for use in the Javelin Command Launch Unit (CLU). Javelin is an anti-tank missile system.

This 0.15-watt cooler was re-qualified in 1999 following an Army funded Manufacturing Technology (Mantech) program with DRS.[2,3] This Mantech program was performed on both the 0.15-watt and 1.0-watt coolers with funding from the US Army Mantech program, the Program Manager for Night Vision Reconnaissance, Surveillance and Target Acquisition (PM-NV/RSTA), and the Program Manager for Javelin. It developed new production techniques and processes that reduced the cost to manufacture the 0.15-watt cooler by 30%. It focused on process improvements to the compressor clearance seals, gas decontamination process, motor manufacturing, and cooler final assembly. It also replaced the compressor helical spring suspension system with a flat plate, flexure spring, suspension system. The goal of changing to a flexure springs system was to simplify motor assembly and double the life of the coolers from 4,000 to 8000 hours MTTF. A significant cost avoidance will be realized due to lower manufacturing costs and higher reliability coolers, and the potential production requirement for more than 7,000 of these coolers in the next 15 years.

The 0.15-watt Javelin cooler with flexure springs is currently in full-scale production. It passed all required Javelin detector dewar cooler assembly performance and qualification tests prior to production.

Three Javelin coolers began life testing on February 1, 1999 at DRS. These life test coolers have accumulated an average of 4777 relevant hours of operation through January 28, 2000. Two units, MSN 18 and MSN 13, have 5289 hours each and the third unit has 3754 hours since being returned to the life test. Javelin cooler numbers 18 and 13 have been failure free. The only anomaly during the period occurred when the chamber failed to hold the prescribed temperatures during the cycle.

1.0-WATT LINEAR DRIVE COOLERS

The 1.0-watt cooler is the focus of significant efforts and investments to qualify multiple sources, reduce manufacturing costs, and increase their reliability. These coolers are used with SADA II, and are critical components of many DoD programs to include the Army's 2nd Generation FLIR Horizontal Technology Integration (2nd Gen. FLIR HTI) program and the improved TOW acquisition system.

Status of Qualification Efforts

The DRS Infrared Technologies 1.0-watt coolers were first qualified in 1997. DRS is one of the main suppliers of 1.0-watt coolers to the Army. AEG Infrared Modules (AIM) of Germany is also a qualified supplier. AIM was qualified in 1998 through a Foreign Comparative Testing (FCT) program with NVESD and the Army's Program Manager for FLIRs (PM FLIR). The FCT program provided funds to purchase and test several AIM coolers. Both cooler manufacturers demonstrated reliability over the 4,000-hour MTTF requirement. DRS coolers accumulated an average of 6,486 hours and the AIM coolers accumulated 4,753 hours.

Qualification testing of Litton Life Support 1.0-watt coolers is near completion. These coolers have passed most formal qualification tests. Only the Electromagnetic Radiation and the reliability tests remain to be completed. The coolers have accumulated an average of 2,500 hours in reliability testing. NVESD and PM FLIR support Litton's formal qualification testing.

Manufacturing Technology (Mantech) Efforts

The 1.0-watt cooler was also the beneficiary of an Army Mantech effort that resulted in a 32% decrease in cooler manufacturing costs at DRS. As mentioned before, this Mantech program was performed on both the 0.15-watt and 1.0-watt coolers with funding from the US Army Mantech program, the Program Manager for Night Vision Reconnaissance, Surveillance and Target Acquisition (PM-NV/RSTA), and the Program Manager for Javelin. This Mantech program focused on manufacturing process improvements to the compressor clearance seals, gas decontamination process, regenerator/expander design, motor manufacturing, and cooler final assembly. The Mantech effort was completed in 1998 with the completion of environmental and reliability tests. This program established a lower cooler price threshold that is impacting the competitive procurement of current and future procurements (12,000 coolers projected in the next 20 years). In order to maximize competition, the Mantech program included a technology transfer effort that provided DRS reports and briefings to approved cooler manufacturers.

Reliability Improvements

The DRS 1.0-watt cooler with flexure springs is currently in qualification and life testing. This effort is funded by the Army's Operation and Support Cost Reduction (OSCR) Program and managed by NVESD. The goal is to increase the life of the 1.0-watt cooler from 4,000 hours to 8,000

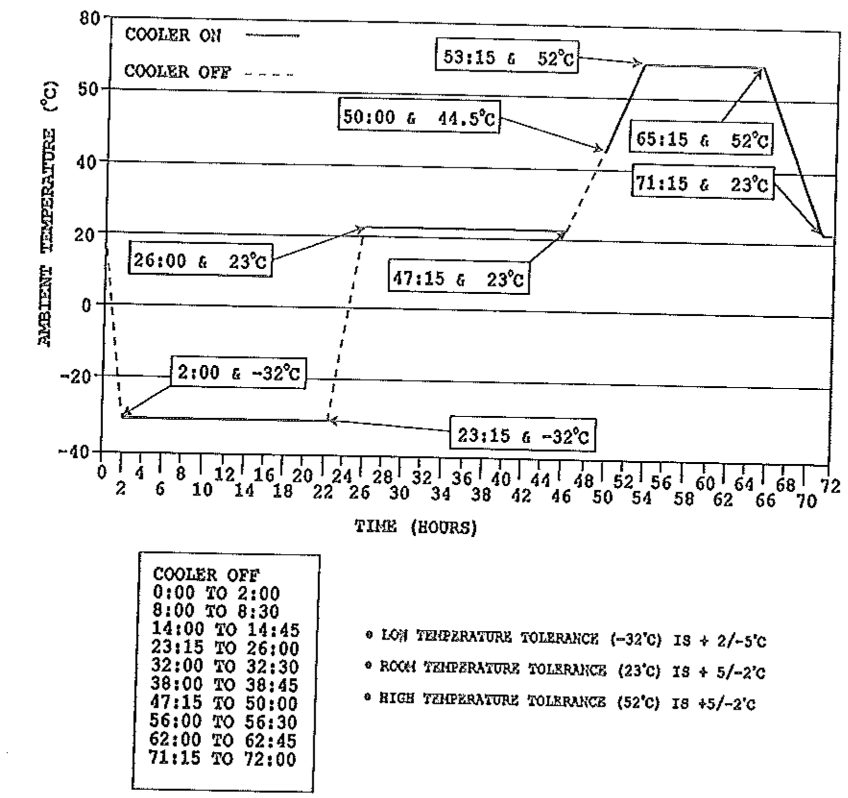

Figure 2. Reliability Test Profile, 1.0-watt linear cooler with external electronics.

hours Mean Time to Failure (MTTF) in order to reduce operation and support costs. The lessons learned in the development of the DRS 0.15-watt Javelin cooler with flexure springs were applied to the 1.0-watt cooler effort.

Figure 2 depicts the reliability test profile for 1.0-watt coolers. Six 1.0-watt coolers with flexure springs have been built, and test results show that they match the performance of the 1.0-watt coolers (helical springs) currently qualified and in production. Several modifications have been necessary since testing started in 1999. One modification deals with the addition of more rugged clamping mechanisms after the flexure spring stack shifted during the mechanical shock and mechanical vibration tests.

Reliability testing on three 1.0-watt coolers with flexure springs began on April 16, 1999. One unit was removed from testing due to unacceptable vibration output levels. A defective magnet assembly caused the unacceptable vibration output levels. This unit was replaced with two additional coolers to total four coolers in life test. These reliability test coolers have surpassed the required 4,000 relevant hours of operation with an accumulated average count of 4,600 hours. Testing will continue until 8,000 hours MTTF are demonstrated or until failure of the coolers. Additional tests are required to demonstrate full conformance to qualification requirements.

1.75-WATT LINEAR DRIVE COOLERS

The 1.75-watt cooler is designed to address the needs of the high performance second generation infrared imaging systems that will use a SADA I or other equivalent performing system whose cooling capacity requirements or faster cool-down times cannot be met with a 1.0-watt cooler. These coolers are currently used in many DoD programs to include the Army's Comanche and Apache helicopters.

Several AIM 1.75-watt coolers were purchased and are undergoing evaluation and formal qualification testing as part of a Foreign Comparative Test (FCT) program with NVESD and the Program Manager for Comanche (PM Comanche). Several 1.75-watt coolers have been successfully integrated into Comanche, Apache, and several other high performance FLIR systems to include Quantum Well FLIRs. The production requirement for these coolers is estimated at over 8,000 in the next 20 years.

FUTURE COOLER EFFORTS

Army efforts will continue to focus on reducing manufacturing costs, improving reliability, and improving the performance of the family of linear drive Stirling cryocoolers.

NVESD, PM NV/RSTA, and PM Comanche are supporting efforts to increase the reliability of 1.0-watt coolers to 12,000 hours MTTF and the 1.75-watt cooler to 8,000 hours MTTF. Fiscal year 2001 funds are possible for these efforts. A related effort will aim to reduce the manufacturing costs of the 1.75-watt coolers through the transfer of manufacturing processes developed under the 1.0-watt and 0.15-watt cooler Mantech program.

With the advent of longer life coolers (8000-12,000 hours) there is a need to develop a method to shorten the reliability testing while demonstrating cooler life. NVESD is exploring alternatives to the current reliability test method. The current test method demonstrates cooler life by actually running the coolers until failure. With the current method the coolers accumulate 450 hours of runtime per month. It will take 30 months to demonstrate a 12,0000-hour cooler introduction of a valid accelerated reliability test. The cooler is still the least reliable component in FLIR systems and there is a need to accelerate the introduction of longer life cryocoolers into DoD systems.

SUMMARY

A family of second-generation (2nd Gen.) infrared-imaging critical components called the Standard Advanced Dewar Assemblies (SADA's) has been developed to support a DoD standardization strategy. A family of linear drive coolers has also been established in support of this standardization strategy.

The US Army CECOM Night Vision Directorate in conjunction with several US Army Program Managers has embarked in linear drive cooler efforts aimed at qualifying coolers, reducing cooler prices, and increasing cooler reliability.

Qualification test efforts for the DRS 0.15-watt flexure spring and for the DRS & AIM 1.0-watt coolers were successfully completed in the last five years. Qualification testing for the 1.75-watt AIM cooler and two additional 1.0-watt cooler designs (DRS flexure springs and Litton) is ongoing. Some of the weapon systems supported by these qualification efforts include the Army's Second Generation Forward Looking Infrared (FLIR) Horizontal Technology Integration (HTI), Comanche, Apache, Javelin, Improved TOW Acquisition Sensor, and Long Range Advanced Scout Sensor Suite (LRAS3).

The US Army Manufacturing Technology program and the Operation and Support Cost Reduction program were successful in reducing manufacturing costs and in implementing flexure spring designs aimed at increasing the reliability of the 0.15-watt and 1.0-watt coolers. Additional work is planned to transfer these improvements to the 1.75-watt coolers and to further increase the reliability of 1.0-watt coolers.

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3. DRS Infrared Technologies, "Linear Drive Cooler Mantech Program," Contract DAAB07-95-C-J513 Industry Review, February 1999.

Air Force Research Laboratory Cryocooler Characterization and Endurance Update

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ABSTRACT

The Air Force Research Laboratory (AFRL) has been instrumental in advancing sp cryocooler technology through cryocooler development and characterization of the. long-t performance of different types of cryocoolers. These coolers were developed to support long life space mission requirements of the United States Air Force SBIRS-Low Program fice, the Ballistic Missile Defense Organization (BMDO), the National Aeronautics and Sp Administration and the Department of Defense. Long life cryocooler applications include cc ing infrared sensors, focal planes, optics and electronic circuits for various space missions national interest.

The main objective of this paper is to present the status of the cryocoolers currently unc going characterization and endurance evaluation at AFRL. The information gained through these processes is shared with industry partners, cryocooler developers, technology sponsors, and technology users. This feedback is essential for cryocooler design enhancements and future cryogenic technology development efforts. There are two cryocoolers undergoing characterization at AFRL. These include the Astrium (formerly Matra Marconi Space) 10 K Cryocooler, and the TRW 150 K miniature pulse tube (150K MPT). In addition, there are five cryocoolers undergoing endurance evaluation at AFRL These include the Raytheon Protoflight Spacecraft Cryocooler, Raytheon Standard Spacecraft Cryocooler (SSC) II, TRW 3585, TRW 6020, and the Defense Evaluation and Research Agency (DERA) cryocooler. This paper includes each cryocooler's status, and update or initial report on its performance, elapsed runtime hours, performance anomalies and updated characterization and endurance evaluation data.

INTRODUCTION

The most critical characteristics of cryocoolers for strategic space applications are lifetime and reliability. This is what distinguishes them from their short-term tactical cousins. The primary purpose of the Air Force Research Laboratory Cryogenic Cooling Research Facility (CCRF) is to explore the thermodynamic performance characteristics of one-of-a-kind or first-of-a-kind engineering design model or protoflight space cryocoolers and assess their lifetime and

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July 6, 2015

RE: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, RIN: 1400-AD32

To Whom It May Concern:

ChemImage Corporation wishes to comment on the Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, published on May 5, 2015. ChemImage Corporation is a small chemical imaging company founded and headquartered in Pittsburgh, PA. Our products utilize hyperspectral chemical imaging technologies for chemical and biological applications in numerous industries, including forensic analysis, threat detection, pharmaceutical testing, and biomedical imaging.

ChemImage Corporation uses short-wave infrared (SWIR) InGaAs focal plane arrays in many of its products. Our technologies integrate these InGaAs focal plane arrays into permanently encapsulated sensor assemblies, which secure the focal plane array inside the product. Our products are dual-use in nature. Our LightGuard and VeroVision products, for example, may be configured to detect a wide range of chemicals and can distinguish innocuous compounds such as sugar and salt from various drugs, explosives, and explosive precursors. They are, in essence, molecular materials analysis tools suitable for a vast range of applications, from detecting ice on a roadway to identifying illicit drugs in prison mail. We have marketed these products for wide area surveillance monitoring at everything from sporting events to airport screenings.

Under the current rule, InGaAs focal plane arrays are captured under Category XII(c) of the ITAR. This has introduced significant challenges to our development and marketing of our products. The current Category XII is designated as Significant Military Equipment, and, as such, requires the completion and submission of DSP-83 form with the request of an export license. We have found great barriers in applying for demonstration licenses to exhibit our products at trade shows, and are challenged by the length of time involved in applying for and receiving licenses. For a company whose products may be configured to detect innocuous as well as harmful chemicals, the months-long procedure to merely ask permission for a demonstration—with no transfer of technology or materiel—has been onerous.

To that end, we wish to comment on the proposed rule for Category XII, specifically on sections (c)(2) and (c)(6). First, we wish to ask for clarification on what is meant by a "multispectral detector," and request that this be further defined in this section. Second, we request clarification on the term "integrated into a permanent encapsulated sensor assembly." Does the proposed rule require a particular standard of permanence? With regards to the proposed Category XII(c)(6), we find the drafting unclear. Section (c)(2) indicates that "multispectral detectors…having a peak response within the wavelength rage exceeding 900nm but not exceeding 30,000 nm and <u>not</u> integrated into a permanent encapsulated sensor assembly" are included under the section, but Section (c)(6) contradicts by stating that "Multispectral IRFPAs in a permanent encapsulated sensor assembly, having a peak response in any spectral band within the wavelength range exceeding 1,500 nm but not exceeding 30,0000" (emphasis added). This language invites further confusion for companies like ChemImage, who use SWIR focal plane arrays using wavelengths from 900 nm to 1700nm, fully encapsulated in a permanent sensor assembly.

While we are aware that the current Category XII(c) states "military infrared focal plane arrays identified…are licensed by the Department of Commerce …when part of a commercial system," the current proposed draft of Category XII invites more confusion for us. We reiterate the fact that cameras such as those used in our products may be used for a variety of non-military applications, and that the continual placement of such components on the U.S. Munitions List provides a chilling effect to companies both large and small.

We urge you to clarify the proposed language within Category XII and to remove the inherent barriers to marketing and selling systems that integrate SWIR focal plane arrays under the ITAR.

Should you wish additional comment from ChemImage Corporation, please do not hesitate to contact the undersigned at santosj@chemimage.com or via telephone at 412-241-7335 x234.

Sincerely,

Juvyrose V. Santos
Export Compliance Officer, ChemImage Corporation

July 6, 2015

Sent via email to: publiccomments@bis.doc.gov and DDTCPublicComments@state.gov

Regulatory Policy Division
Bureau of Industry and Security
U.S. Department of Commerce
Room 2099B
14th Street and Pennsylvania Avenue NW
Washington, DC 20230

and

Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
Bureau of Political Military Affairs
Department of State
Washington, DC 20522

Subjects: RIN 0694-AF75 - Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the United States Munitions List (USML)

and RIN 1400-AD32 Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

Dear Sir or Madam:

The Computing Technology Industry Association (CompTIA) is a non-profit trade association serving as the voice of the information technology industry. With approximately 2,000 member companies, 3,000 academic and training partners and nearly 2 million IT certifications issued, CompTIA is dedicated to advancing industry growth through educational programs, market research, networking events, professional certifications and public policy advocacy.

Thank you for the opportunity to provide comments on the Export Administration Regulations (EAR) proposed rule which describes how articles the President determines no longer warrant control under Category XII (Fire Control, Range Finder, Optical and Guidance and Control

Equipment) of the United States Munitions List (USML) of the International Traffic in Arms Regulations (ITAR) would be controlled under the Commerce Control List (CCL) by creating new ``600 series'' Export Control Classification Numbers (ECCN)s 6A615, 6B615 and 6D615 for military fire control, range finder, and optical items, by revising ECCN 7A611 and by creating new ECCNs 7B611, 7C611 and 7E611 for military optical and guidance items. In addition, for certain night vision items currently subject to the EAR, this rule proposes to expand the scope of control, eliminate the use of some license exceptions, and create new ECCNs for certain software and technology related to night vision items. This proposed rule would also expand the scope of end-use restrictions on certain exports and reexports of certain cameras, systems, or equipment and expand the scope of military commodities described in ECCN 0A919.

The Department of State rule proposes to amend the ITAR to revise Category XII of the USML to describe more precisely the articles warranting control on the USML.

Optics technologies are playing a key role across many industries today. In the commercial automotive sector for example, LIDAR, radar, and camera systems are being used to anticipate and prevent crashes and significantly improve passenger safety. In early June, the National Transportation Safety Board recommended vehicle manufacturers install forward collision avoidance systems as standard features on all newly manufactured passenger and commercial motor vehicles since the technology would be capable of preventing nearly 4,500 rear-end crashes per day. Similarly, in the aviation sector, LIDAR technologies are playing a key role in providing the imagery necessary for the provision of adequate geographic information as a part of the FAA's NextGen program, aimed at improved aviation efficiency and safety. Given these key use cases, and many others, CompTIA's members are committed to ensuring that these critical technologies continue to advance and provide vital public and private sector benefits, as changes to the USML Category XII take place.

CompTIA has the following comments on RIN 1400-AD32 and RIN 0694-AF75:

> ***Cat. XII(b)(6): Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);***
>
> ***Note to paragraph (b)(6): This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less.***

This proposed provision would capture LIDAR systems used in self-driving car applications even if the system is solely designed for civil automotive applications. This is because it would not qualify for the "Note to paragraph (b)(6)" (hereinafter, referred to as "Civil Automotive Exception"). Specifically, a system would not meet the criteria of the Civil Automotive

Exception if the range of the LIDAR system exceeds the range of 200m. It is our belief that many commercial companies are developing self-driving car LIDAR technology that would indeed exceed 200m. In particular, we believe that the range must exceed 200m for safety reasons. For example, the system's range needs to be greater than 200m when the vehicle is making unprotected left turns in the presence of cars that are driving at higher speeds regardless of whether they decelerate or not. A greater than 200m range is also necessary for spotting oncoming emergency vehicles so that the self-driving car can safely pull over and move out of the path of such vehicles. Furthermore, in rural areas where speed limits tend to be higher, being able to detect oncoming traffic at a greater range than 200m is again important from a safety perspective.

Recommendation: We request that the range in the Civil Automotive Exception be increased to 400m to account for current technology developments geared towards safety on the road as well as future innovation in this space.

> ***Cat. XII(b)(8): LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geigermode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements.***

This proposed provision potentially captures LIDAR systems used in civil automotive applications. Specifically, "incoming" bandwidth refers to detector bandwidth and determines minimum resolvable pulse length, which, in turn, drives minimum detectable feature separation. For a self-driving car, a sufficiently short light pulse and the ability to resolve this pulse allows the car to effectively distinguish between objects that are positioned on the same vector with respect to the car, and that are spatially close, such as a pedestrian standing near a car. Detector bandwidth determines the minimum width (in the time domain) of a resolvable pulse, which corresponds to the physical length of a collection of photons in the spatial domain. A long light pulse of 10ns (which would equate to 100 MHz) is 3 m long and could reflect off a pedestrian and also a vehicle 1m away from the pedestrian; a light pulse of 1ns (which would equate to 1000 MHz) is 30 cm long and would have separate reflections off the pedestrian and vehicle generating much more of an accurate read-out of obstacles in the vicinity. In short, having a bandwidth of 1000 MHz allows the system to distinguish between objects/people that are spatially close and on the same vector and to react accordingly to achieve road safety goals. A clock bandwidth of 100 MHz is lower than many common operating bandwidths; the clock in a processor that would control even a trivial LIDAR system could be expected to run faster than 100 MHz. Furthermore, a receiver analog bandwidth of 100 MHz is lower than a common detector and amplifier could be expected to have (and much slower than many currently available components). If the proposed control is intended to address “incoming” or detector bandwidth, it would likely capture many standard commercially available LIDAR systems that are intended and designed for civil automotive self-driving car applications.

In addition to the bandwidth considerations noted above, we also put forth that the trigger point of 128 elements is too restrictive from a safety perspective for civilian self-driving car applications. Specifically, such cars need a LIDAR system to detect with accuracy foreign objects and debris (“FOD”) on the road. The typical range of angle of slope on a road is +/-8 deg. The car needs to be a certain distance away from the FOD in order to react to it safely (150 m), and a typical dangerous FOD is 15 cm tall. This means that the sensor requires on the order of 250 detectors to cover the complete field of view with enough resolution to maintain safety.

Driver-assistance cars do not need this same level of FOD detection mainly because a driver would be able to step in and react whereas in a self-driving car, the system itself needs to react. As such, this parameter, as currently worded, would actually discourage safety for civilian self-driving cars.

Foreign availability: we note that many foreign manufacturers have developed technology in this space. Specifically, Reigl, an Austrian company, Sick AG, a German company and Hokuyo LTD, a Japanese company have all developed LIDAR systems that operate at over 100 MHz. The companies FirstSensor, Hamamatsu and SensL also develop similar systems for commercial applications.

Recommendation: We request that the same Civil Automotive Exception (with the amendment of extending the range to 400 m) that appears in the Note to paragraph (b)(6) be included in (b)(8) to avoid capturing commercial LIDAR systems that are designed and intended for use in civil automotive applications.

If the intention is to capture “incoming” or detector bandwidth, we recommend that the limit be increased to 1000 MHz which would cover a standard LIDAR system designed for civil automotive applications. We also recommend that the element trigger be “greater than 256 elements.” Both of these changes would serve to encourage companies working in this space to continue to work on critical safety features.

> ***Cat. XII(b)(13) Laser stacked arrays as follows: (ii) Having an output wavelength exceeding 1,400 nm but less than 1,900 nm and a peak pulsed power density greater than 700 W/cm^2***

This control would potentially capture Laser stacked arrays that are intended to be incorporated into commercial LIDAR systems since the wavelength range 1400-1900 nm is being used for commercial applications.

Recommendation: We request that the same Civil Automotive Exception (with the amendment of extending the range to 400 m) that appears in the Note to paragraph (b)(6) be included in (b)(13)(ii) to avoid capturing commercial LIDAR systems that are intended for use in civil automotive applications.

> ***Cat. XII(c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;***

Due to the extremely wide range of wavelength parameter, this sweeping control would potentially capture IRFPAs that are intended by design and function for use in commercial LIDAR systems used in self-driving cars. Such IRFPAs, including highly sophisticated arrays, are currently under the jurisdiction of the Commerce Department so this proposed control would have the effect of placing commercially world-wide available EAR-controlled IRFPAs under ITAR jurisdiction. This would not only have devastating effects on US businesses, but it will also serve to bolster foreign competitors' efforts in this space. Indeed, many companies may elect to move operations abroad and source commercially available non-US components to avoid the hugely negative impact of these controls.

With respect to the term "focal plane array" itself, it is unclear whether detector elements that are purchased separately on multiple chips but are ultimately put together on a plane would actually qualify as a "focal plane array."

Additionally, linear arrays (single line of detectors) can only form images when coupled to a scanning system, which makes them very inefficient for night vision applications, but are necessary to form the 360 degrees field of view that self-driving vehicles require.

Foreign availability: Many non-US companies have IRFPAs that would be caught by this control. For example, Hamamatsu, a Japanese company, has an array in the range of 900-1600 nm that would be caught.

Recommendation: Include an exception/carve out for IRFPAs that are specially designed and intended for use in LIDAR systems used in civil automotive applications and having a peak response within the wavelength range not exceeding 1800 nm. Also, we recommend amending the definition of an IRFPA to include the monolithic nature of it (and exclude arrays formed of multiple dies assembled together in a system) as well as exclude linear arrays.

> ***Note 1 to paragraph (c): A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) prevents direct access to the IRFPA, disassembly of the***

sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

§ 772.1 Definitions of terms as used in the Export Administration Regulations (EAR). Permanent encapsulated sensor assembly. (Cat 6) A permanent encapsulated sensor assembly (e.g. sealed enclosure, vacuum package) containing an infra-red focal plane array (IRFPA) that prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

To our knowledge, the term "permanent encapsulated sensor assembly" is not an industry-wide used term. As such, using this term will inevitably lead to confusion as well as inconsistency in how it is applied when interpreting the related controls. Even with the definition provided in Note 1 to paragraph(c) as well as in sec. 772.1 of the EAR, it is hard to apply since the requirements of the definition in their strictest sense cannot be met. Specifically, as far as we are aware, many focal plane arrays that are in some sort of encapsulation can still be disassembled without damaging or destroying the IRFPA. However, this can generally only be done by specialized tools by someone who has detailed awareness of the design of the IRFPA. Is the term "permanent encapsulated sensor assembly" intended to capture closed and non-serviceable encapsulated systems that could be disassembled by a specialized technician using specialized tools without damaging or destroying the IRFPA or is it only intended to capture closed and non-serviceable encapsulated systems that cannot be disassembled without damaging or destroying the IRFPA? If the latter, it is unclear to us whether any assembly would actually meet that criteria.

Recommendation: If the technical data is already controlled and one would need the design technology in order to be able to disassemble the assembly without damaging or destroying the IRFPA, it makes sense to modify this note as well as the definition set forth in sec. 772.1 of the EAR to read as follows: "*A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) is designed as a closed and non-serviceable system intended to prevent direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA.*"

Note 1 to paragraph (f): Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.

Note 1 to paragraph (f) has the potential to yield extremely unreasonable consequences. For example, if Manufacturer A is designing a focal plane array controlled under the EAR, the related design technology would be controlled under the EAR. If Manufacturer B takes that same technology though and designs an ITAR-controlled focal plane array, that design technology that was controlled under the EAR would now become controlled under the ITAR even though it may have nothing to do with the parameters triggering control of the focal plane array under the ITAR.

Recommendation: Both proposed Note 1 and Note 2 should be revised to make clear that technical data that is "directly related" to an ITAR-controlled item (covered by the mentioned controls in the Note) is limited to technology that is specific to the parameters that render the device controlled under the ITAR and would not include generic design technology for focal plane arrays that would be covered under the EAR.

The guidance provided in proposed Note 1 to paragraph (f) of USML Category XII indicates that technical data not "specially designed" for a defense article nonetheless is directly related to the defense article. Such an overly broad reach of "directly related" does not conform to the plain meaning of the term. If certain technical data apply equally to items subject to the EAR as to items subject to the ITAR, then the technical data necessarily, under the recently promulgated "specially designed" definition, are not "specially designed" for defense articles, and so should not be deemed "directly related" to any defense article. "Directly related" should not be taken to mean merely "capable of use with" since that would not only run contrary to the plain meaning of the term, but it would also defeat the definition of "specially designed. Both the State and Commerce Departments explicitly repudiated the "capable of" standard in their definition of "specially designed." That over-reaching standard should not be embedded in "directly related."

Furthermore a definition of "directly related" is needed in order to clarify the export control status of myriad technical data used in or with both defense articles and items subject to the EAR as well as with respect to software. A definition of "directly related" should be promulgated that adheres closely to the natural meaning of the words, *i.e.*, "required and peculiarly responsible for the controlled features" of the associated item. Both "required" and "peculiarly responsible" have commonly understood definitions among the exporting public and those commonly-understood definitions should apply in this context. Alternatively, those terms could be assigned meanings similar to those currently being proposed by both the Commerce Department and State Department in their proposed rules (June 3, 2015) revising certain key definitions within the EAR and the ITAR.

> ***§ 742.6 Regional stability. (a) * * * (8) Special worldwide RS license requirement for specified items controlled in Category 0 or 6. A license is required to export or reexport the following items to all destinations, including Canada: (i) ''Technology'' controlled under ECCN 0E987; (ii) All commodities controlled under ECCNs 6A002; (iii) All***

commodities controlled under ECCN 6A990; (iv) ''Software'' controlled under ECCN 6D002 for the ''use'' of commodities controlled under 6A002.b; (v) ''Software'' controlled under ECCN 6D003.c; (vi) ''Software'' controlled under ECCN 6D991 for the ''development,'' ''production,'' or ''use'' of commodities controlled under ECCNs 6A002, 6A003, or 6A990; (vii) ''Software'' controlled under ECCN 6D994; (viii) ''Technology'' controlled under ECCN 6E001 for the ''development'' of commodities controlled under 6A002 or 6A003; (ix) ''Technology'' controlled under ECCN 6E002 for the ''production'' of commodities controlled under 6A002 or 6A003; (x) ''Technology'' controlled under 6E990; and (xi) ''Technology'' controlled under ECCN 6E994.

This proposed regional stability reason for control imposes a worldwide licensing requirement for items classified under several ECCNs. Not only is this type of global control unprecedented under the EAR, but, in addition, it is being imposed on several items that were previously classified as EAR99 (e.g., those items covered under newly created ECCNs 6D994 and 6E994 as well as the additional items that will now be caught under the proposed re-wording of ECCN 6A990 which would expand its scope to include ROICs for *all focal plane arrays* controlled under 6A002a.3). In short, this means that items that previously required no license at all (except for export to the embargoed countries) will now require an export license to be shipped everywhere including Canada. Needless to say, this will result in a huge burden on industry as well as the Commerce Department, which will have to process both additional export/reexport and deemed export/deemed reexport license applications for the covered items. Since projects involving this type of technology and source code have not been thus far subject to restrictive export controls, it is highly likely that non-US nationals have already been working on them and continue to work on them today. It is also fairly common for collaboration on projects to occur across offices and across countries. The proposed control would require limiting cross-country collaboration, restricting those who can work on the projects to US nationals and/or obtaining licenses for all non-US nationals working on the project. Applying for export and deemed export licenses would impose a large burden on both the Commerce Department and industry, as described earlier, and raises other issues caused by a shift in licensing policy, described further below. It will also inevitably affect the marketability of US parts and components as well as software and technology.

(b) Licensing policy.—(1) Licensing policy for RS Column 1 items or items subject to worldwide RS control…(iv) Applications for exports or reexports of software or technology described in paragraphs (a)(8)(i), (a)(8)(iv), (a)(8)(v), (a)(8)(vi), (a)(8)(viii), and (a)(8)(x) will be reviewed with a presumption of denial. There is also a presumption of denial for technology described in paragraph (a)(8)(ix), unless it is ''build-to-print technology'' that is required for integration, mounting, inspection, testing, or quality assurance (e.g., necessary to meet International Standards Organization (ISO) certification), which will be reviewed on a case-by-case basis.

Under the proposed licensing policy for items subject to the RS worldwide control, many items that are currently EAR99 (items controlled under the proposed rewording of 6A990) in addition to numerous other items controlled under 6A002, 6D003.c, and 6E001 that were eligible for various license exceptions would now be subject to a licensing policy of denial. This shift in licensing policy, creation of a worldwide licensing requirement, and removal of eligibility of certain license exceptions serve to pseudo-treat these items as ITAR-controlled even though these items are actually currently controlled under the EAR. This would serve to potentially severely impact US industry as companies seek alternative options that would not be tainted by US export licensing policies in this space. Similar long-lasting repercussions were seen in the space and satellite industry when those areas were subjected to ITAR control and foreign companies then looked to suppliers outside the US (with some foreign companies specifically desiring to go "ITAR free") to avoid subjecting their products and technologies to control under the ITAR. In our view, this would not fall within the spirit of export control reform.

> ***6D991 ''Software,'' n.e.s., ''specially designed'' for the ''development'', ''production'', or ''use'' of commodities controlled by 6A002, 6A003, 6A990, 6A991, 6A996, 6A997, or 6A998.***

The proposed revision to 6D991 results in controlling software that is currently controlled as EAR99 (e.g., software “specially designed” for the “development,” “production,” or “use” of all 6A002 and 6A003 items). Furthermore, the reason for control of RS would result in a license being required for all covered software to all countries and non-US nationalities in the case of deemed exports. Again, controlling this type of software would be fairly disruptive to industry since much of this software is currently non-controlled. Moving from a state of non-control to a state of highly-controlled will inevitably result in large impact from a licensing perspective as well as from a cross-nationality and cross-country collaboration perspective. Finally, such a control will help further non-US business interests working in this space whose software and technology are not subject to unilateral US export controls.

> ***6D994 ''Software'', n.e.s., ''specially designed'' for the maintenance, repair, or overhaul of commodities controlled by 6A002, 6A003, or 6A990.***

> ***6E994 ''Technology'' ''required'' for the maintenance, repair, or overhaul of commodities controlled under 6A002, 6A003, or 6A990.***

The proposed creation of ECCNs 6D994 and 6E994 would result in controlling low-level software and technology that is currently non-controlled (i.e., EAR99) and already developed abroad by various non-US focal plane array manufacturers. Furthermore, the reason for control of RS would result in a license being required for all covered software and technology to all countries and non-US nationalities (in the case of deemed exports). Thus, we would move from a regulatory environment of not requiring any export or deemed export licenses (except for the embargoed countries) to one where licenses would be required for all covered items regardless of destination or nationality. Again, we believe this would create a significant burden on both US companies and BIS. Further, it would serve to ultimately hurt US businesses by having the secondary effect of encouraging the use of non-US manufacturers and developers so as to avoid the draconian implications that would result from using items that are subject to ITAR-like licensing requirements and policies.

Thank you once again for the opportunity to provide comments on these proposed rules.

Sincerely,

Ken Montgomery
Vice President, International Trade Regulation & Compliance

From:	Susan Palmer
To:	publiccomments@bis.doc.gov; DDTCPublicComments
Subject:	ITAR Amendment -Category XII
Date:	Monday, July 06, 2015 5:00:39 PM

Cordin Company, Inc.
2230 South 3270 West
Salt Lake City, Utah 84119
USA
July 6, 2015
Department of Commerce
Bureau of Industry and Security
publiccomments@bis.doc.gov

RE: RIN 1400 AD 32 Public Comments on the Amendment to the International Traffic in Arms Regulations: Revision of the U.S. Munitions List Category XII.

Cordin has additional comments on how the ITAR proposed changes will negatively impact Cordin Company as business based in the USA.

Cordin Company has one strong competitor who sells in the US but systems are manufactured in the UK. This competitor is Specialized Imaging. They sell a SIM D intensified Gated CCD Camera very similar to our Cordin Model 222-4G gated intensified system and also a SIM X camera also a competitor. They also distribute Optronis image converter cameras in direct competition with the Cordin Model 164. The Specialized Imaging systems also compete with our Rotating Mirror Streak and framing cameras, Cordin Model 131 and Model 131-HD rotating mirror CCD streak cameras and Cordin Model 580 and Model 560 rotating mirror framing cameras. Specifications for these systems manufactured by Cordin and by Specialized imaging are included with this document.
As we mentioned before Cordin is shrinking in size and Specialized imaging located in the UK is growing. Specialized Imaging is not subject to the strict regulations already in force by the Commerce Department, nor will they be limited in the future by any of the proposed ITAR additional restrictions.

Cordin is directly affected by any changes in regulations relating to photocathode tubes, micro channel plate intensifiers that also contain photocathode tubes, focal plane arrays and optical components such as beam splitters and cooling devices or readout devices and software.

Some of the regulations will directly affect our Cordin systems now, but many of the others will affect us in the future. If this becomes law these components will be controlled and therefore a prohibiting problem for us in the future as our competitor will be allowed to use any of the controlled components without being regulated. These regulations will essentially not only cause us a problem in our current design but also by deciding what directions we will be allowed to pursue in the future. In a few years all the new technology you seek to control will no longer be cutting edge but it will still remain controlled by ITAR and we will have difficulty in using these items to improve our systems that must commercially sell in the US and outside of the US in order for us to compete with Specialized Imaging.

This is evidenced by the fact that the rotating mirror camera systems were designed in the 1940’s and detailed schematics of these systems are widely available worldwide. Numerous books were published in Europe detailing how to design and build a rotating mirror camera system. Our rotating mirror camera system basic design has now been known to the world for over 70 years and still it is on control. Once an item becomes mired in the Export Licensing system it is never removed regardless of its availability by other vendors outside of the USA. This policy has resulted in the fact that only one US company (Cordin) has been able to survive to the present in the USA when there were multiple companies that manufactured here in the 1950’s and 1960’s before the Export Licensing was instituted.

Specific regulations are written vaguely to allow coverage of various categories of imagers and parts to allow flexibility in your control of these items. This makes it very difficult for Cordin to determine what parts can be incorporated into our systems in the future.

The regulation Category XII (2) (A) sections 1-5. These could include almost anything we use to design our camera systems or that our competitor uses to design and we must make a similar design to compete with them in the commercial and military markets.

The regulation proposed Note to paragraph (b) (14) Sections (1) and (2). This may not apply immediately to technology but again future designs may require that we use these components with the increased spectral ranges or sensitivity. This paragraph will cripple our ability to innovate our image converter Model 164 and intensified gated cameras Model 222-4G and could also affect our our rotating mirror camera designs.

The regulation proposed Note to paragraph (c) (2) Section 12. This again is likely not included in our current camera systems, but again if we cannot use these components or assemblies in the future we are not able to keep up with the competition that is no similarly limited.

The regulation proposed Category XI (a) (4) This section in total will limit any improvements to our camera systems in the future buy limiting spectral ranges, cooling devices. The Model 131-HD rotating mirror streak camera will be captured on the ITAR regulation list because we combine the information on 11 CCD’s into one file. This regulation if instituted could, if interpreted strictly. put almost all of our existing camera systems on the ITAR program, if not now in the near future.

Again all the components that you are trying to regulate that are included in cameras that can be used in military operations are also of value in high speed streak and framing cameras. The high speed cameras we sell are already regulated as a dual use item, even this regulation is prohibiting as the out of the USA competition does not have this problem. Our cameras are used for research and are not of any value on a battlefield. If these cameras are caught in the ITAR regulations also we will be even more severely penalized to the point that we may not be able to continue our operation.

Susan Palmer, Sales Manager Cordin Company, Inc. 2230 South 3270 West, Salt Lake City, Utah 84119   susan@cordin.com 8801 972-5272 ex 213.

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SIMX - Ultra High Speed Framing Camera

UNITED STATES
Choose Your Country

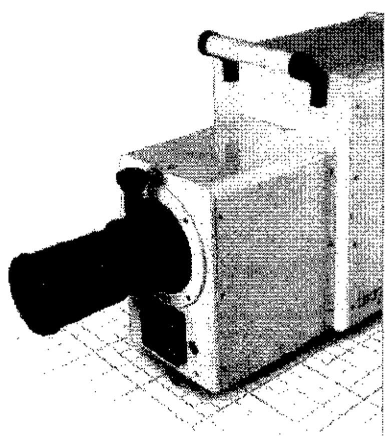
Overview

Using high resolution image intensifiers and no-compromise optical design, provides high quality ultra fast framing images.

High quality images free from lag or ghosting.

50lp/mm dynamic resolution

MULTI-SPECTRAL IMAGERY



The Specialised Imaging Ultra Fast Framing Cameras offer the ultimate in ultra-high-speed imaging performance to scientists and engineers across all disciplines. The all-new custom optical design offers up to 16 images without compromising shading, or parallax. High resolution intensified CCD sensors controlled by state-of-the-art electronics provide almost infinite control over gain and exposure to allow researchers the flexibility to capture even the most difficult phenomena.

Full remote control using Ethernet is offered as standard, either the integral viewfinder or a laptop computer can be used for local focus. Comprehensive triggering facilities, highly accurate timing control, and a wide range of output signals, coupled with a custom software package that includes full measurement and image enhancement functions simplifies image capture.

All SIM cameras can be configured to give up to 16 different multi-spectral images with an R, G and B filter on each channel. In this configuration it is possible to take 10 colour images and 2 monochrome.

Applications

- **Ballistics**
- **Combustion Research**
- **Failure Dynamics**
- **Elasticity, Crack Propagation and Shock resistance**
- **Medical Research and testing**
- **Detonics**
- **Impact Studies**

Features

- **NEW Multi-Spectral Imaging Functions**
- **Up to 16 discrete intensified optical channels**
- **Hybrid beamsplitter to overcome parallax and improve resolution**
- **Viewfinder focus**
- **Customisable spectral response**
- **1360(H) x 1024(V) 12 bit images**

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Universal Image Intensifier Improves Low Light Performance of High Speed Camera / Video Systems

Specialised Imaging has introduced a new high speed relay lens to enable easy interfacing of its SIL2 range of image intensifiers to almost any high speed camera or video system.

The SIL2 family of gated image intensifier systems has been proven to improve the sensitivity, gating time, and spectral response of both high-speed video... **READ MORE**

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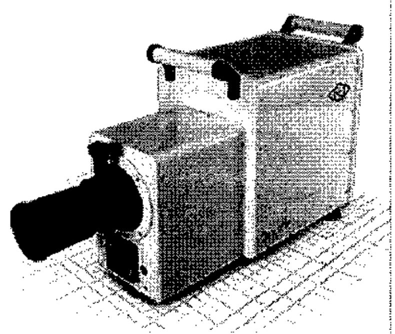
SIMD - Ultra High Speed Framing Camera

Overview

Using high resolution image intensifiers and no-compromise optical design, provides high quality ultra fast framing images.



Double Pulse technique giving up to 32 images.

36lp/mm dynamic resolution

MULTI-SPECTRAL IMAGERY

The Specialised Imaging Ultra Fast Framing Cameras offer the ultimate in ultra-high-speed imaging performance to scientists and engineers across all disciplines. The all-new custom optical design offers up to 16 images without compromising shading, or parallax. High resolution intensified CCD sensors controlled by state-of-the-art electronics provide almost infinite control over gain and exposure to allow researchers the flexibility to capture even the most difficult phenomena.

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Applications

- Ballistics
- Combustion Research
- Failure Dynamics
- Elasticity, Crack Propagation and Shock resistance
- Medical Research and testing
- Detonics
- Impact Studies
- Spray and Particle Analysis
- Automotive testing
- Nanotechnology and micro-machines

Features

- NEW Multi-Spectral Imaging Functions
- Up to 16 discrete intensified optical channels
- Hybrid beamsplitter to overcome parallax and improve resolution
- Viewfinder focus
- Customisable spectral response
- 1360(H) x 1024(V) 12 bit images

Related Products

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Latest News

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Specialised Imaging

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Email info@specialised-imaging.com

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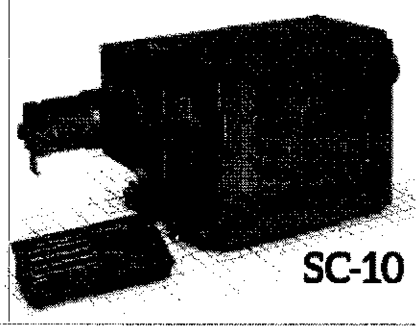
Model SC-10

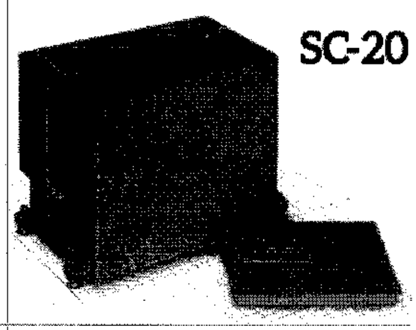
SC-10 offers time resolution down to < 2 picoseconds. It has a large 8 mm photocathode and a 20 mm long streak length making it one of the largest format picosecond streak cameras available.



The SC-10 offer a modular design to allow both UV and Visible optics. Single Shot and Synchroscan sweep modules cover time windows from 200 psec. to 100 ms. making the widest range system on the market. An externally mounted fiber coupled MCP Intensifier and a variety of CCD readout cameras offer sensitivity and resolution to give single photoelectron sensitivity and high speed data transfer. Input optics are available to allow coupling to all spectrographs for time resolved spectroscopy, to VISAR systems and other optical setups including microscopes.

Model SC-20

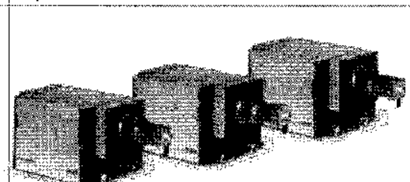
The SC-20 Streak Camera offers time resolution down to < 200 picoseconds. It has a large 35 mm photocathode and 40 mm streak lengths making it the largest format streak cameras available.



SC-20 offers a modular design to allow for UV or Visible inputs, both fiber optic and lens coupling, Single Shot sweep modules cover time windows from 100 nsec. to 100 ms. making it the widest range system on the market. An externally fiber optic coupled MCP Intensifier and a variety of CCD readout cameras offer resolution and sensitivity to give single photoelectron sensitivity and high speed data transfer. Input optics are available to allow coupling to most spectrographs for time resolution spectroscopy, to VISAR systems and other optical setups including microscopes.

Versatility

We offer several variants of the above camera systems to include X-ray, UV, VIS and NIR applications.



Both the SC-10 and SC-20 offer very high spatial resolution for multi line recording from Spectrographs, Line VISAR and other spatial resolution applications. SLR lenses can be mounted directly to the input optics for imaging events at long distances. Fiber Optic Coupled Time Markers allow for insertion of optical pulses to be superimposed on to the streak to allow post processing and calibration of the data. All cameras offer electro mechanical shutters to protect the photocathodes.

All systems offer photocathode gating to eliminate pre and post event light to improve signal to noise in your data. We offer the Highest resolution Readout Systems with up to 4K x 4K pixels at up to 16 bits dynamic range, and fiber coupling for maximum sensitivity. We offer Optically coupled CCD Readout System with up to 150 fps data transfer.

Specialised Imaging

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Temecula CA 92590
United States

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Model 580

HIGH SPEED ROTATING MIRROR CCD CAMERA

CORDIN

SCIENTIFIC IMAGING

HIGH SPEED ROTATING MIRROR CCD CAMERA

Model 580

- **Very high resolution:** 8 megapixel, (3.2K x 2.4k) at all capture speeds
- **High dynamic range:** 14 bit ADC
- **Very high framing rate:** 4 million fps
- **Very high image quality**
- **Software control:** easy control of exposure and timing parameters for each channel through user-friendly software
- **Image alignment software:** post processing software for precise alignment of images for animation and analysis
- **Laser and pulsed flash illumination synchronization**
- **Built-in time delay functions**

The **Cordin Model 580** high-speed rotating mirror CCD camera achieves the highest combination of speed and resolution of any imaging technology available. The Cordin 580 captures images in a burst mode at frame rates of 4 million frames per second and at 8 mega-pixel resolution. The system uses a rotating mirror optical system, which does not require reading out sub-arrays of the image to achieve higher framing rates. It also allows for much higher frame counts and no image degradation relative to MCP based high speed camera systems, and enables color imaging.
The ADC dynamic range for this camera system is a 14 bits and images are captured at full frame size 3.2K x 2.4K at all speed ranges. The camera is available in a 20, 40 or 78 frame configuration. Frames can be either black and white or color. Systems purchased with fewer frames can be upgraded to more frames at a later date.
The Model 580 camera can be triggered by the event being photographed, and can accept triggers in advance or for some time after the event of interest. It can also provide the trigger to initiate the event.
The standard high speed mirror-drive is driven by compressed air or nitrogen at lower to medium speeds, and with helium at higher speeds. The camera can also be configured with a brushless electric driven mirror operating at slower speeds, for more convenient operation when high framing rates are not required.
The system comes complete with a computer and control software. Post processing image alignment software that provides precise alignment of images for animation and analysis is also included. Data may be saved in a wide variety of 8 bit file formats. Full 14 bit images are saved in 16 bit tiff file format.

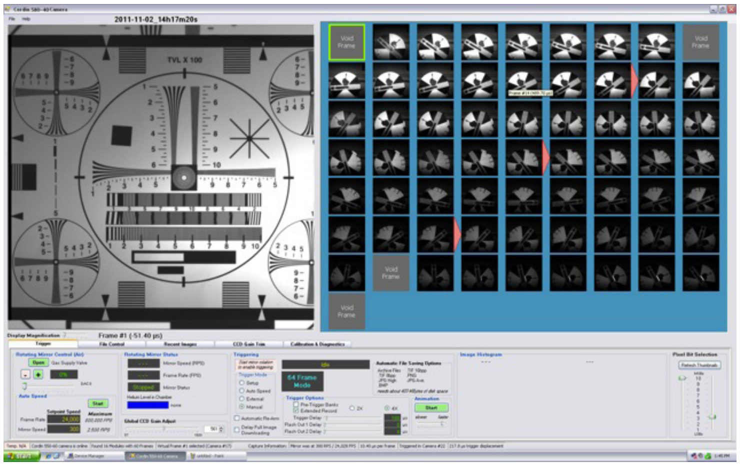
OPTIONS

Customized front optics	Cordin Enlarging ~5X lens
Micro or Macro lens options	Illumination Sources Models 605, 607
C- Mount Adapter	Mobile camera stand

Model 580

HIGH SPEED ROTATING MIRROR CCD CAMERA

CORDIN
SCIENTIFIC IMAGING



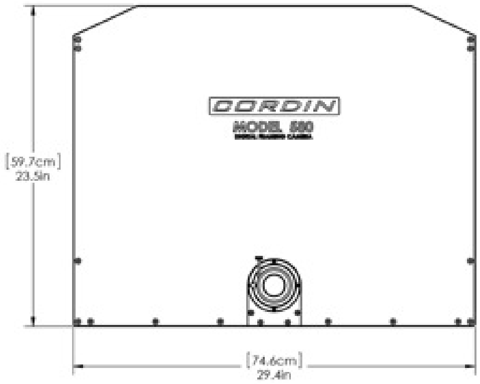
Screen shot of the Model 580 user interface

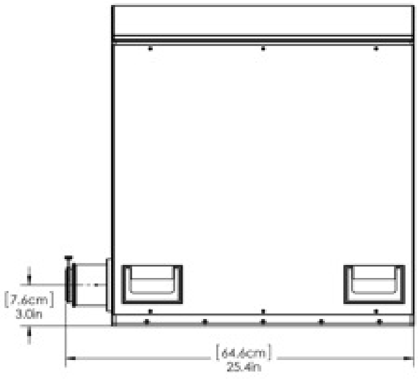
SPECIFICATIONS

Number of Frames	20, 40 or 78
Maximum Framing Rate	4 million fps (78 frames)
Front Optics	Single objective lens system (no parallax)
Objective Lens	Nikon F-mount
Resolution	3.2K x 2.4K pixels, 1.6K x 2.4K pixels with binning
Pixel size	5.5 x 5.5 µm
ADC Dynamic Range	14 Bit
Device Type	Full resolution progressive scan Black and white standard Color optional
Interface	Gigabit Ethernet for camera control and image transfer

CONFIGURATIONS

Number of Frames	20	40	78
Gas Turbine Drive Configuration			
Maximum Framing Rate (fps)	1,000,000	2,000,000	4,000,000
Minimum Interframe time	1 µs	500 ns	250 ns
Minimum Exposure Time	220 ns	220 ns	220 ns
Electric Drive Configuration			
Maximum Framing Rate (fps)	150,000	300,000	600,000
Minimum Interframe time	6.6µs	3.3 µsec	1.7 µsec
Minimum Exposure Time	1.46 µs	1.46 µs	1.46µs





Model 560

HIGH SPEED ROTATING MIRROR CCD CAMERA

CORDIN

SCIENTIFIC IMAGING

HIGH SPEED ROTATING MIRROR CCD CAMERA

Model 560

- **High resolution:** 2 megapixel, (1920 x 1080) at all capture speeds
- **High dynamic range:** 14 bit ADC
- **Very high framing rate:** 4 million fps
- **Very high image quality**
- **Software control:** easy control of exposure and timing parameters for each channel through user-friendly software
- **Image alignment software:** post processing software for precise alignment of images for animation and analysis
- **Laser and pulsed flash illumination synchronization**
- **Built-in time delay functions**

The **Cordin Model 560** high-speed rotating mirror CCD camera offers high resolution at extremely high framing rates, and at a moderate cost. The Cordin 560 captures images in a burst mode at frame rates of 4 million frames per second and at 2 mega-pixel resolution. The system uses a rotating mirror optical system, which does not require reading out sub-arrays of the image to achieve higher framing rates. It also allows for much higher frame counts and no image degradation relative to MCP based high speed camera systems, and enables color imaging.
The ADC dynamic range for this camera system is a 14 bits and images are captured at full frame size 3.2K x 2.4K at all speed ranges. The camera is available in a 20, 40 or 78 frame configuration. Frames can be either black and white or color. Systems purchased with fewer frames can be upgraded to more frames at a later date.
The Model 560 camera can be triggered by the event being photographed, and can accept triggers in advance or for some time after the event of interest. It can also provide the trigger to initiate the event.
The standard high speed mirror-drive is driven by compressed air or nitrogen at lower to medium speeds, and with helium at higher speeds. The camera can also be configured with a brushless electric driven mirror operating at slower speeds, for more convenient operation when high framing rates are not required.
The system comes complete with a computer and control software. Post processing image alignment software that provides precise alignment of images for animation and analysis is also included. Data may be saved in a wide variety of 8 bit file formats. Full 14 bit images are saved in 16 bit tiff file format.

OPTIONS

- Customized front optics
- Micro or Macro lens options
- C- Mount Adapter
- Cordin Enlarging ~5X lens
- Illumination Sources Models 605, 607
- Mobile camera stand

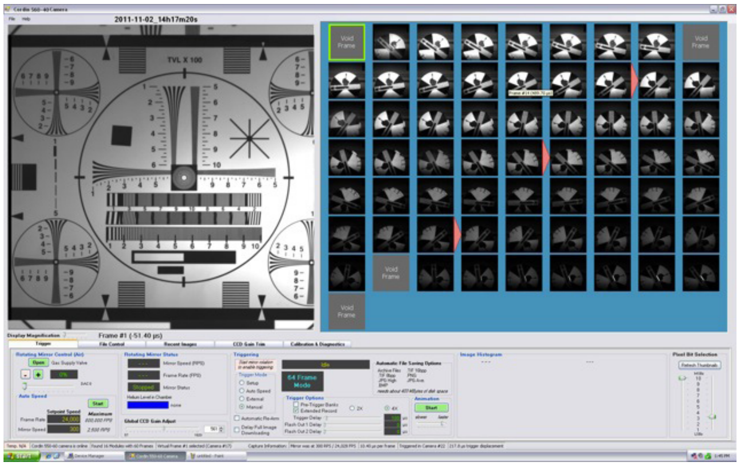
 2230 South 3270 West, Salt Lake City, Utah 84110 USA 801-972-5272

Model 560

HIGH SPEED ROTATING MIRROR CCD CAMERA

CORDIN

SCIENTIFIC IMAGING


Screen shot of the Model 560 user interface

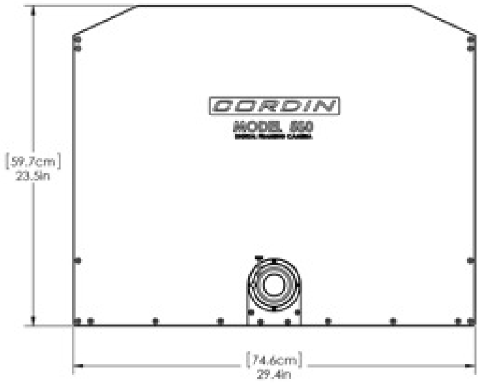
SPECIFICATIONS

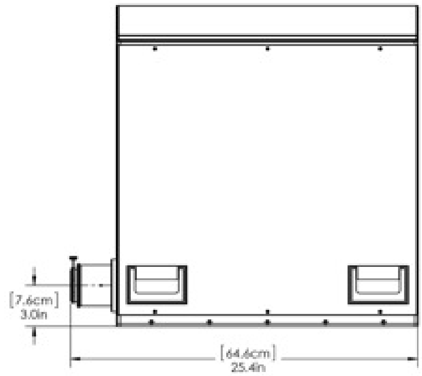
Number of Frames	20, 40 or 78
Maximum Framing Rate	4 million fps (78 frames)
Front Optics	Single objective lens system (no parallax)
Objective Lens	Nikon F-mount
Resolution	1920 x 1080 pixels

Pixel size	7.4 x 7.4 µm
ADC Dynamic Range	14 Bit
Device Type	Full resolution progressive scan Black and white standard Color optional
Interface	Gigabit Ethernet for camera control and image transfer

CONFIGURATIONS

Number of Frames	20	40	78
Gas Turbine Drive Configuration			
Maximum Framing Rate (fps)	1,000,000	2,000,000	4,000,000
Minimum Interframe time	1 µs	500 ns	250 ns
Minimum Exposure Time	220 ns	220 ns	220 ns
Electric Drive Configuration			
Maximum Framing Rate (fps)	150,000	300,000	600,000
Minimum Interframe time	6.6µs	3.3 µsec	1.7 µsec
Minimum Exposure Time	1.46 µs	1.46 µs	1.46µs





Model 222-4G

HIGH SPEED GATED INTENSIFIED CCD CAMERA

CORDIN

SCIENTIFIC IMAGING

HIGH SPEED GATED INTENSIFIED CCD CAMERA

Model 222-4G

- **Very high image quality**
- **High resolution CCD,** 2K x 2K pixels, 12 bit dynamic range
- **Extremely short exposure time,** down to 5 ns
- **Very high sensitivity,** enabling very short exposures in moderate light or microscope configurations
- **Very high framing rate,** minimum interframe times equivalent to 200 million frames per second
- **Independent control of gain,** exposure time and time delay for each channel
- **Display adjustment** sliding scale to view 8 bit subsamples of full 12 bit images on the fly

The **Cordin Model 222-4G** gated, intensified multi-channel CCD camera offers the best image quality of any multi-channel intensified camera available. It is a powerful and easy to use tool for studying events in the nanosecond to millisecond time domain. The camera system is based around a beam splitter optical system that distributes the image from a single objective lens to eight separate imaging channels without vignetting, parallax or ghosting. Each channel has an MCP device fiber-optically coupled to a 4MPixel CCD, and can capture two images per channel, for a total of 16 images captured by the system.
Time between exposures on adjacent channels can be as short as five nanoseconds. Time between exposures on a single channel can be as short as one microsecond.
Operation of the camera is controlled via USB 2.0 with user-friendly software that allows the user to set timing, sequence, gain and triggering. 12 bit images can be saved as TIFF or RAW files, and any 8 bit subsampled image can be saved as BMP or JPG files. Camera settings can also be saved and reloaded later to duplicate a set-up.
The 222-4G is a thoroughly new design, building on Cordin's 15 years of experience in this technology.

OPTIONS

Microscope integration

Tele-focus macro objective lens

Alternate photocathode materials for choice of wavelength range sensitivity

UV configuration

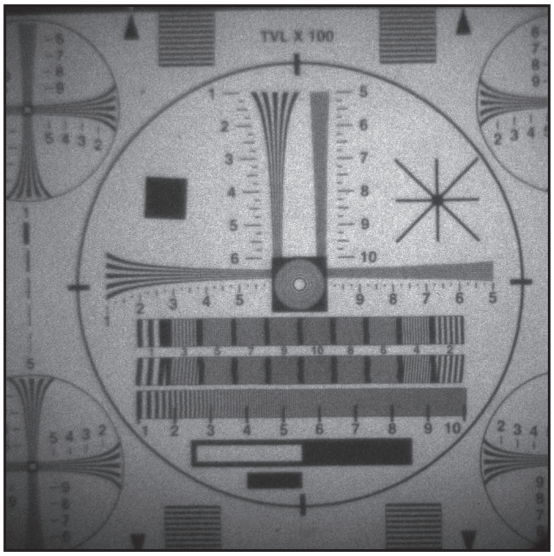
Available with fewer channels at a lower cost, with option of adding channels later as an upgrade

Model 222-4G

HIGH SPEED GATED INTENSIFIED CCD CAMERA

CORDIN

SCIENTIFIC IMAGING



Raw Image of Resolution Chart at 5ns exposure

SPECIFICATIONS

CCD

Pixels	2048 x 2048
Device Type	Full resolution progressive scan
Dynamic Range	12 bit

INTENSIFIER

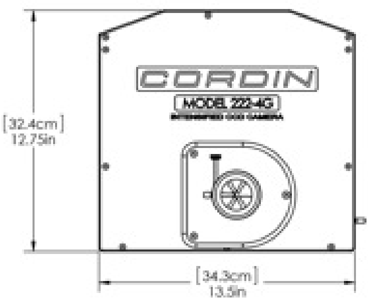
Device	18 mm Ø MCP
Photocathode	Super S25
Gain	10,000 watts/watt
Shutter Ratio	107:1
Grey Scale	42 dB to 48 dB
Resolution	40 lp/mm

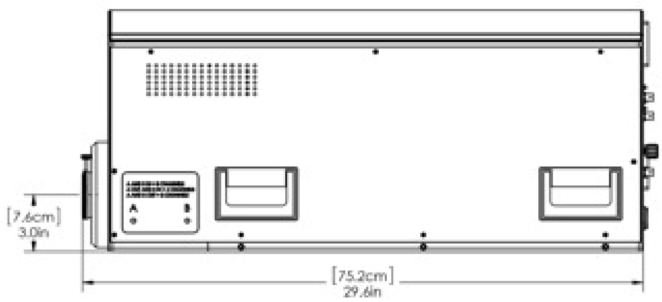
OPTICS

Number of Images	16 images on 8 channels
Objective Lens	Nikon F mount
Beam Splitter	Pellicle mirror system

TRIGGERING AND INTERFACE

Interframe Times	5 ns to 10 ms in 5 ns steps with independent control of each frame
Exposure Times	5 ns to 1 ms in 5 ns steps
System Response	65 ns maximum
Jitter	±3 ns
Input Triggers	Logic Level, direct and isolated; Analog and Optical with threshold
Outputs	Monitor, two programmable LVDS outputs on common time base with images
Interface	USB 2.0





CORDIN

SCIENTIFIC IMAGING

IMAGE CONVERTER STREAK CAMERA

Model 164

- **Wide photocathode,** 18mm x 4mm
- **High spatial resolution,** 30 lp/mm
- **High temporal resolution,** 50 picoseconds
- **Very low noise,** 10^{-8} Cd/m^{2}
- **High resolution readout,** 12 bit, 4 megapixel CCD

Streak cameras record a thin, wide line of light signals at the fastest possible speeds. They capture subtle variations in intensity from a line image, a spread spectrum, or linear array of discrete signals with resolution down into the picoseconds.

The **Cordin Model 164** streak camera is the evolution of Cordin's more than 20 years of experience in streak camera design and manufacturing. It uses a streak tube with a large photocathode and high spatial resolution to give a broad range of data capture capability. It has an integrated, high resolution, high dynamic range CCD readout that ensures all information is captured in both detail and gray scale.

The 164 comes standard with a photocathode offering spectral sensitivity from 350nm to 1100nm. Sensitivity ranges covering from 115nm to 1550nm are available.

The entrance slit is a user adjustable mechanical slit, so that resolution versus input energy can always be optimized. The input optics have an easily accessible telecentric region for drop-in filters.

The camera is controlled via a standard USB interface and a Windows PC. The host software allows for control of all camera functions, triggering and delays, image acquisition, display, and basic image analysis.

OPTIONS

Nikon lens mount for imaging

Spectrograph coupling for time resolved spectroscopy

Multi-channel fiber optic linear array input for optical signal analysis

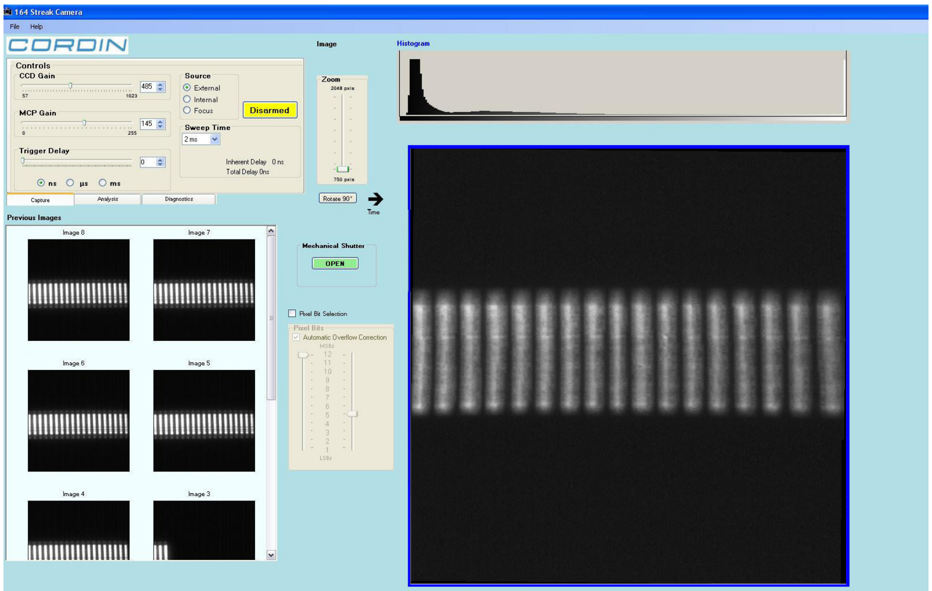
Alternate photocathode materials for choice of wavelength range sensitivity

UV configuration

Model 164

IMAGE CONVERTER STREAK CAMERA

CORDIN
SCIENTIFIC IMAGING



Screen shot of the Model 164 user interface

SPECIFICATIONS

STREAK

Temporal Resolution	50 picoseconds
Spatial Resolution	30 line pair/mm
Spectral Response	350-1100 nm standard 115-1550 nm optional
Photocathode	18 mm x 4 mm
Sweep Nonlinearity	less than 10%

INTENSIFIER

Device	25 mm Ø MCP
Photocathode	Super S25
Gain	10,000 watts/watt
Shutter Ratio	107:1
Grey Scale	42 dB to 48 dB

CCD READOUT

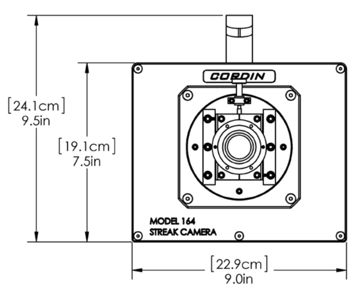
Pixels	2000 x 2000
Device Type	Full resolution progressive scan
Dynamic Range	12 bit

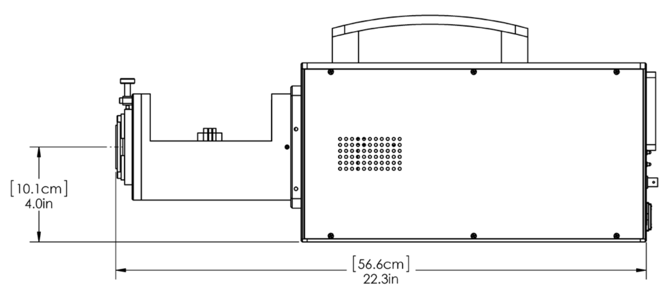
TRIGGERING AND INTERFACE

Response Time	less than 35 nanoseconds
Jitter	less than 50 picoseconds
Trigger Input	+5V
Interface	USB 2.0 to Windows 7 host

GENERAL

Power Input	110-250VAC 50-60 Hz
Weight	14 kg (32 lbs)





Model 131-HD

HIGH SPEED ROTATING MIRROR STREAK CAMERA

CORDIN

SCIENTIFIC IMAGING

HIGH SPEED ROTATING MIRROR STREAK CAMERA

Model 131-HD

- **Very high spatial resolution,** 6400 pixels
- **Fast temporal resolution,** down to 650 ps
- **Software control** of exposure and timing parameters
- **Laser and pulsed flash illumination synchronization**
- **Long record length,** up to 46,000 pixels
- **Re-triggerable within seconds**
- **14 bit image depth**
- **Programmable time delay functions**
- **Captures external electronic fiducial inputs** on common time base
- **Electronic shuttering** prevents image overwrite

The **Cordin Model 131-HD** camera is the ideal analytical tool for continuously measuring one dimension over time for a given event. The rotating mirror architecture provides long record length and recording rate flexibility. Combining rotating mirror and CCD technology provides users with access to digital streak image information in seconds. This allows the researcher to record data ready for subject adjustment, analysis, or presentation. A unique opto-mechanical design provides a continuous digital streak record, without gaps, blemishes, and with negligible distortion.

The Model 131-HD streak image is 6400 pixels in the spatial axis, and 17,000 pixels along the temporal axis. Optional extended record configurations offer up to 46,000 pixels on the temporal axis.

The Model 131-HD is offered with two alternative rotating mirror turbines: the standard 1209 turbine operates to 5,000 rps and the optional 1231 turbine operates to 7,500 rps. The turbines can reach 50% of full speed using compressed air or nitrogen. Helium is required to reach full speed.

The writing rate is determined by the speed of the rotating mirror, which is software controlled. At top speed, using the 1209 turbine the recording rate is 4,460 pixels per microsecond. The 1231 turbine at top speed yields a recording rate of 6,700 pixels per microsecond.

Two fiducial inputs are provided for precise image synchronization. Two programmable delayed outputs are also provided. An intuitive PC-based user interface allows for easy setup, acquisition, alignment, analysis and saving of data.

OPTIONS

Extended record length to 46,000 pixels

High speed turbine (Model 1231)

Optical fiducial mark generator

Custom objective optics

Custom slit configurations

Laser field of view alignment tool

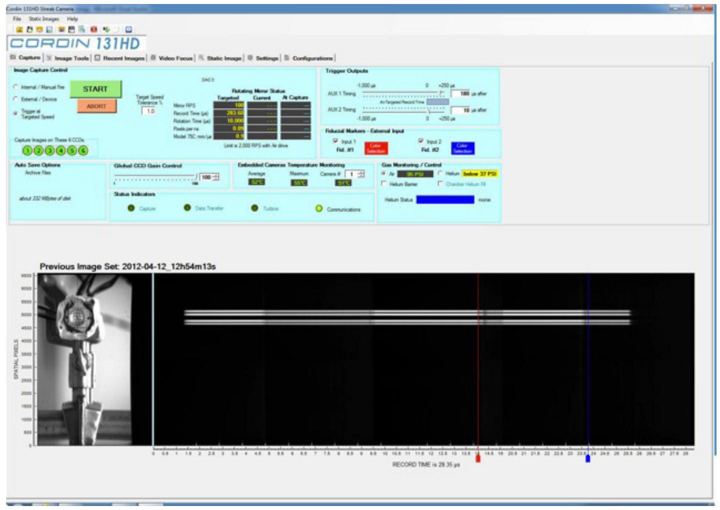
 2230 South 3270 West, Salt Lake City, Utah 84119 USA 801-972-5272 www.cordin.com

Model 131-HD

HIGH SPEED ROTATING MIRROR STREAK CAMERA

CORDIN

SCIENTIFIC IMAGING



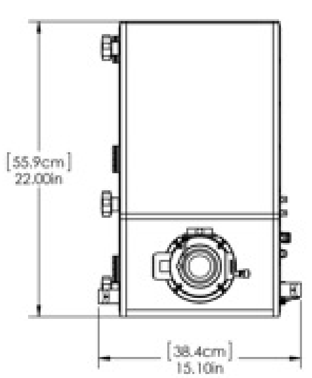
Screen shot of the Model 131-HD user interface

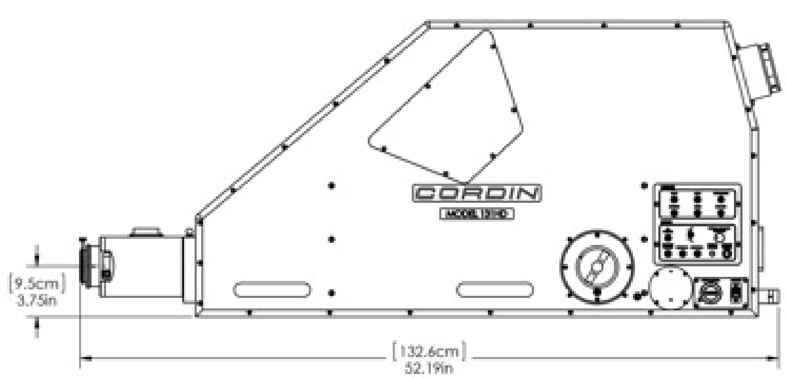
SPECIFICATIONS

Record Width	6400 pixels
Record Length	17,000 pixels standard
Extended Track Length	21,000, 34,000 or 46,000 pixels *optional*
Minimum Temporal Feature	4.5 pixels at 25 micron slit width
ADC Dynamic Range	14 bit
Radius of Image Arc	400 mm
Subtended Angle of Arc	13 degrees standard, 37 degrees maximum
Objective Lens	Nikon F-mount standard
	Other objective optics available
Pixel Size	5.5 x 5.5 microns
Device Type	29 MPixel full resolution progressive scan
	Black and white standard

Data Interface	Gigabit Ethernet
Trigger Inputs	+5V, +5V isolated, analog and optical with threshold
Fiducial Inputs	Two independent channels captured on common time base
Delay Outputs	Two programmable delay channels on common time base

Turbine	**MODEL 1209**	**MODEL 1231**
Max Mirror Rotation	5000 rps	7500 rps
Temporal Resolution	1.0 ns	0.65 ns
Record Length		
17,000 Pixel Configuration	3.8 µsec	2.6 µsec
46,000 Pixel Configuration	10.2 µsec	7.0 µsec





CORDIN
SCIENTIFIC IMAGING

HIGH SPEED ROTATING MIRROR STREAK CAMERA

Model 131

- **Very high spatial resolution,** 3,250 pixels
- **Fast temporal resolution,** down to 1.4 ns
- **Software control** of exposure and timing parameters
- **Laser and pulsed flash illumination synchronization**
- **Long record length,** up to 28,300 pixels
- **Re-triggerable within seconds**
- **14 bit image depth**
- **Programmable time delay functions**
- **Captures external electronic fiducial inputs** on common time base
- **Electronic shuttering** prevents image overwrite

The **Cordin Model 131** rotating mirror streak camera is the ideal analytical tool for continuously measuring one dimension over time for a given event. The rotating mirror architecture provides long record length and very high resolution compared to other streak capture methods. Combining rotating mirror and CCD technology provides users with access to digital streak image information in seconds. This allows the researcher to record data ready for subject adjustment, analysis, or presentation. A unique opto-mechanical design provides a continuous digital streak record, without gaps, blemishes, and with negligible distortion. Image information is captured at very fast rates without a photon-electron conversion. This means dynamic range is very high and image noise is very low.

The Model 131 streak image is 3,250 pixels in the spatial axis, and 14,000 pixels along the temporal axis. Optional extended record configurations offer up to 28,300 pixels on the temporal axis.

The Model 131 has large pixels at 7.4 micron pitch. This allows for better dynamic range, as the saturation threshold of the pixels is relatively high. The Model 131 is offered with two alternative rotating mirror turbines: the standard 1209 turbine operates to 5,000 rps and the optional 1231 turbine operates to 7,500 rps. The turbines can reach 50% of full speed using compressed air or nitrogen. Helium is required to reach full speed.

The writing rate is determined by the speed of the rotating mirror, which is software controlled. At top speed, using the 1209 turbine the recording rate is 1,700 pixels per microsecond. The 1231 turbine at top speed yields a recording rate of 2,500 pixels per microsecond.

Two fiducial inputs are provided for precise image synchronization. Two programmable delayed outputs are also provided. An intuitive PC-based user interface allows for easy setup, acquisition, alignment, analysis and saving of data.

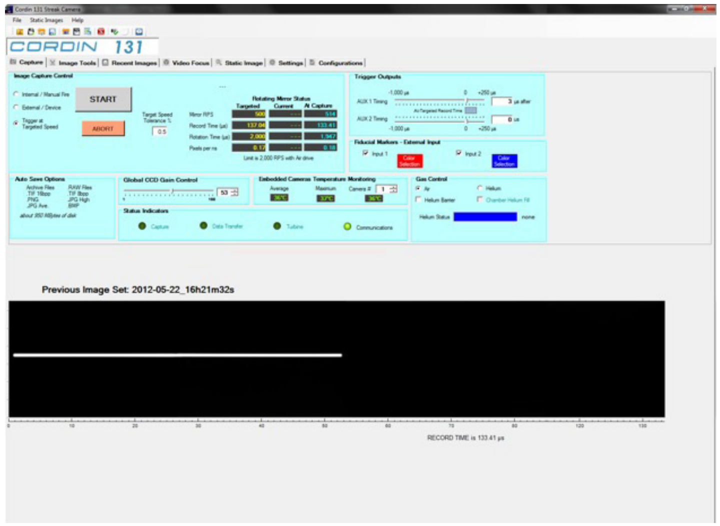
OPTIONS

Extended record length to 28,300 pixels
High speed turbine (Model 1231)
Optical fiducial mark generator
Custom objective optics
Custom slit configurations
Laser field of view alignment tool

CORDIN
SCIENTIFIC IMAGING

Model 131

HIGH SPEED ROTATING MIRROR STREAK CAMERA



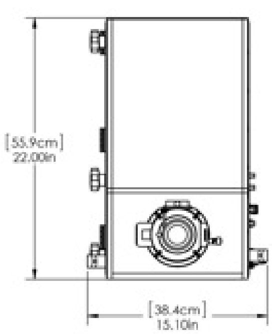
Screen shot of the Model 131 user interface

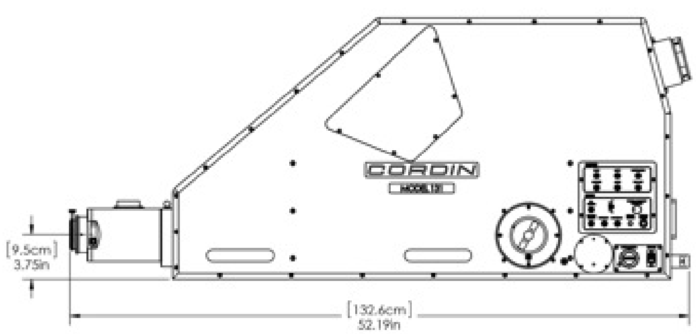
SPECIFICATIONS

Record Width	3,250 pixels
Record Length	14,300 pixels standard
Extended Track Length	28,300 optional
Minimum Temporal Feature	3.4 pixels at 25 micron slit width
ADC Dynamic Range	14 bit
Radius of Image Arc	
Subtended Angle of Arc	
Objective Lens	Nikon F-mount standard Other objective optics available
Pixel Size	7.4 x 7.4 microns
Device Type	29 MPixel full resolution progressive scan Black and white standard
Data Interface	Gigabit Ethernet

Trigger Inputs	+5V, +5V isolated, analog and optical with threshold
Fiducial Inputs	Two independent channels captured on common time base
Delay Outputs	Two programmable delay channels on common time base

Turbine	MODEL 1209	MODEL 1231
Max Mirror Rotation	5000 rps	7500 rps
Temporal Resolution	2.0 ns	1.4 ns
Maximum Writing Rate	1,700 pix/µs	2,500 pix/µs





SYSTRON DONNER
INERTIAL

July 5, 2015

U.S. Department of State
Bureau of Political-Military Affairs
Department of Defense Trade Controls
2401 E Street, N.W.
12th Floor, SA-1
Washington, D.C. 20522

SUBJECT: ITAR Amendment—Category XII

Dear Sirs:

Systron Donner Inertial thanks the Department of State for the opportunity to submit comments for the above proposed rule. We support the Department's objective of establishing a positive United States Munitions List (USML). In response, we provide the following comments:

Paragraph (d) Guidance, navigation, and control systems and equipment:

Inertial sensor and systems nomenclature. We recommend that inertial sensor and systems nomenclature reflect designations in the EAR CCL Category 7: Accelerometers, Gyroscopes, Airborne INS, Land INS, Marine INS, IMU, and AHRS. Consistent nomenclature would be helpful to industry and the government in relating one classification to another and driving consistency among requirements.

Note to paragraph (d)(1). We recommend deleting "Note to paragraph (d)(1)" as well as removing and reserving USML Cat IV(h)(1), Cat VI(f)(4) & Cat III(c)(1). This would place controls for the same/similar technology for all guidance, navigation and control systems in XII(d) instead of multiple USML categories.

Note 1 to paragraph (d)(2). We recommend deleting "Note 1 to paragraph (d)(2)." All accelerometers (other than possibly Cat XV) should be controlled in this category.

Note 3 to paragraph (d)(2). We recommend clarifying the measurement of 'bias' and 'scale factor' to refer to one sigma standard deviation with respect to a fixed calibration over a period of one year.

Product line performance. We recommend that a note be added to clarify how the performance levels should be applied: are the performance levels applied against the product line or against each individual system produced in the product line. It is recommended that performance levels be applied against the product line; otherwise, there could be instances in which specific items from a product line would fall under USML CAT XII and other items from that product line would fall under EAR CCL Category 7. The product line could be expensive to produce if the license category is not definite before product completion for delivery.

Performance parameters.
We recommend the following performance parameters for USML Category XII:

Gyroscope: 0.0005 deg/√Hr

We recommend lowering the gyro Angle Random Walk performance value from 0.00125 deg/√Hr to 0.0005 deg/√Hr to better align the gyro with the accelerometer and INS performance values in Category XII. Angle Random Walk is clearly defined by the industry by using the Allan Variance technique.

INS:

Provide distinct performance parameters for INS configured for airborne, land and marine applications will make it easier for both industry and government to understand what is covered by Category XII:

Airborne INS	0.28 nmph CEP; at a 1 hour period
Land INS	0.28 mrad secant (Lat)
Marine INS	0.2 nm in 8 hour period, CEP

We recommend inserting a statement that INS performance is determined without position-aiding devices.

IMU:

Industry has two ways in which to describe IMU performance: the performance of the gyros and accels which make up the IMU, or as an equivalent INS performance expressed in nmph CEP. The proposed USML performance values would result in a bit of an asymmetry since the gyro performance levels are more consistent with an 0.8 nmph CEP performance. Changing to the proposed gyro performance would provide the proper balance.

Given the high performance parameters for inertial items in Category XII, we recommend removing USML paragraph entry XII(d)(1)(iii) and eliminating the “or 25 g” performance requirement. We assume that the objective of Category XII is to control inertial performance of strategic value while controlling the lower performance inertial items by the EAR CCL. The 25 g “or” condition will result in lower performance inertial systems remaining under USML.

<u>Paragraph *(f) Technical data and defense services:</u>

Notes 1, 2, & 3 to paragraph (f). We recommend the United States Government confirm their intent not to control any technical data or software which is not enumerated in these notes. As stated in the Supplementary Information of this proposed rule, these notes are revised to clearly describe the technical data and defense services controlled in paragraph (f). Note 2, paragraph A, enumerates what software and technical data are "included" in paragraph (f). It does not make any reference or enumerate any entries in paragraph (d); therefor as written, any technical data, including manufacturing know-how, of a USML accelerometer, gyroscope, or INS are no longer enumerated on the USML. If it is the intent of the United States Government to still control this data on the USML, we recommend a complete review of Notes 1, 2 & 3 to paragraph (f).

Category XII Title:
We recommend adding an additional clarifying comma to title; "Fire Control, Range Finder, Optical, and Guidance and Control Equipment"

We appreciate the opportunity to comment on the proposed rule.

Sincerely,

Dean Johnson
General Manager
Systron Donner Inertial
djohnson@systron.com

DELPHI

July 6, 2015

Department of State
Submitted online via Federal Rulemaking Portal

Re: RIN 1400-AD32 Amendment to the International Traffic in Arms Regulations: Revision of US Munitions List Category XII

Dear Mr. Edward Peartree and others it concerns,

Delphi Automotive ("Delphi") is a leading global supplier of mobile electronics and transportation systems, including powertrain, safety, electrical/electronic architecture, controls and security systems.

Delphi's Electronics and Safety Division, is a leader and innovator in the design and manufacture of vehicular sensing systems (including LIDAR) for both Advanced Driver Assistance Systems (ADAS) and automated vehicular applications

Delphi has the following comments regarding the proposed rule changes:

Delphi appreciates the intent to recognize that certain LIDAR systems used in civil automotive applications be exempted from the export control restrictions as delineated in paragraph (b)(6):

Paragraph (b)(6) is added for certain light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems and includes a carve out for certain LIDAR systems for civil automotive applications.

Note to paragraph (b)(6): This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less

Delphi is concerned, however, that the 200m range restriction for automotive LIDARs places too strict of a limit both for ADAS applications that exist today and for future automated vehicle applications that may place higher requirements on sensor performance. Today, premium adaptive cruise control (ACC) systems for longitudinal vehicular control often require sensing ranges up to 250m in order to assure safe and proper vehicle control in scenarios where there is a large speed differential between host and target vehicles. Specifically, the 250m range requirement has typically been derived from an autobahn scenario where a very high delta velocity exists between a host vehicle (that may be traveling above 200km/h) and a much slower moving or stopped target vehicle, – and there is a need to sense the presence of the target vehicle at a long enough range to allow the system to (1) identify the target, (2) classify the target as a threat in the path and (3) actuate a safe level of braking (such as 0.3g) to bring the host vehicle to the required lower speed or to a stop. While LIDARs are not generally in use for such applications today, there is a strong likelihood that requirements for initial forward-looking automated vehicle applications would be identical and thus apply to LIDARs used in civil automotive applications.

DELPHI

Sensor requirements for higher levels of automated vehicle applications are yet to be defined, but Level 3 and Level 4 automated vehicle applications (as defined by NHTSA – those that allow the driver to be completely out of the loop for extended periods) require the vehicle to autonomously handle very complex scenarios. Sensor requirements for these applications are very likely to increase beyond the definition for ACC systems because the time required by the sensor to process and understand such a complex scene, evaluate options for vehicle action and take action or, if necessary, alert the driver to take over control of the vehicle because the situation cannot be safely handled in an automated manner, will increase. While it is not possible to say with certainty today what requirements would evolve to, it is possible to define a scenario where the ideal range requirement for a sensor could double to 500m to address very complex scenarios. Today, cost-effective technology that is capable of performing to these requirements is not available, but it is reasonable to expect that advancements will be made that may extend sensing range to support growing needs.

If comparable sensors are available in other countries without export restrictions, another potential consequence of this restriction is disproportionate harm to US companies from a competitive perspective. This could lead to loss of jobs and technical development expertise in the US.

Considering the above assessment, Delphi recommends that the range limit defining the exemption for LIDARs used in civil automotive applications be extended to at least 250m and that consideration be given to "future-proofing" the carve-out such that evolving needs in automotive applications are addressed. Such future-proofing action might include extending the range limit for civil automotive applications to 500m or more, or enabling a mechanism for speedy re-evaluation of range limits as automotive requirements evolve.

Please feel free to contact me with any questions. We would also be open to meeting to discuss if appropriate.

Sincerely,

Puneet Saxena
Director, Product Regulatory Affairs
Delphi Automotive Systems, LLC
5725 Delphi Drive, Troy MI 48098

Phone: 248-813-1156
E-mail: puneet.saxena@delphi.com

From:	Meredith Downing
To:	DDTCPublicComments
Subject:	Regulatory Change, USML Category XII.
Date:	Monday, May 04, 2015 7:15:22 PM

Hello.

I am trying to determine the effect the proposed new rulings would have on our company and products.

We are a US design and manufacturer (Arizona) of mobile LCD monitors that are installed in systems where NVG or similar mechanisms (Flir) are utilized; when built out a specific way, our products have NVIS-reading (filtering) capabilities. Per the Commodity Jurisdiction ruling of September, 2013, when our monitors are equipped with NVIS-filtering capabilities, we become ITAR-controlled under USML Category XII(c).

I have sent a similar inquiry to BIS, and aside from asking for a new Commodity Jurisdiction ruling (last on received 9-2013), I am trying to confirm that our product remains under USML Category XII or is it moved to BIS? And if it stays with USML, does the subcategory (c) change. I have read through the proposed changes, and Category XII(c) makes consistent references to radar systems versus NVIS-filtering. I am unclear what subcategory our product might be moved to, or is it now eliminated from ITAR-control and moved to EAR99 (BIS), when equipped with NVIS-filtering capabilities? Today, without the integration of NVIS-filtering capabilities per the September 2013 CJ, our product is EAR99.

Please advise. We ship this ITAR-controlled product ship out of the country, so have been applying for DSP-5 licenses through DDTC. We have an order with the destination to our US Military Bagram Airfield, in Afghanistan, and need to understand if the license application now goes through BIS or stays with DDTC.

I also am trying to get confirmation that we can ship ITAR-controlled (or EAR99 if that is where our NVIS-capable unit is moved) to the US Military Bagram Airfield, in Afghanistan.

And is there a possibility EAR99 shipped out of the US will require a license through BIS, not DDTC?

Thank you for your time.

Respectfully,
Meredith Downing
Quality Assurance and Service Manager
480.515.1110 x118; 480.515.0144 (fax)
meredith.d@digitalsys.com

dse
technology in motion

Digital Systems Engineering
An ISO9001:2008 / AS9100C Registered Company
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Scottsdale, AZ 85255-6324
www.digitalsys.com

DRS TECHNOLOGIES
A Finmeccanica Company

DRS Technologies, Inc.
Trade Compliance Office
2345 Crystal City Drive
10th Floor
Arlington, VA 22202

July 6, 2015

Mr. C. Edward Peartree
Director, Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
U.S. Department of State
Washington, DC 20522-0112

Subject: Response to the Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII - 80FR25821

Dear Mr. Peartree,

DRS Technologies, Inc. appreciates the opportunity to comment on proposed revisions to the ITAR related to USML Category XII, Fire Control, Range Finder, Optical and Guidance and Control Equipment. The rule proposes to control as military many items that are widely available outside the United States, in countries that all control them as commercial. These items comprise a portion of the U.S. high-technology industrial base including infrared, night vision, lasers, optics, and gyro-stabilized gimbals. Given the detrimental effect on the commercial space industrial base that the similar approach to control had, we have significant concerns regarding the negative impact that such controls will have on these industries.

We have attached to this letter our specific comments regarding the proposed rule along with a sampling of brochures of foreign available equivalent commercial items that are proposed for control by this rule. The following are our general comments.

One of the main tenets of the President's initiative to reform the U.S. export control system is to "place higher walls around fewer things" by controlling sophisticated military articles and technology, those sensitive military items that the U.S. has a technological lead in, while moving less sensitive items used by the military to the control of the Department of Commerce. The latter items are considered commercial/dual use technologies. Unfortunately, the proposed ECR changes to USML Category XII intend to control as military many infrared, laser, gimbals, and optics items that are commercial/dual use and available from world-wide sources in countries that already control these items as commercial.

For example, uncooled infrared focal plane arrays are presently manufactured by at least nine (9) companies operating in seven (7) countries outside the United States. Three (3) of these companies are located in China. All seven (7) of these countries control these items as commercial/dual-use items. The proposed rule change would restrict only the export of the products manufactured in the United States as these products would be designated military articles. Similarly, only US manufacturers of some high intensity lasers would be restricted from exporting their products while those lasers manufactured in several countries overseas -- all of which control these items as commercial products - would be able to sell them at will. Again, the proposed changes will severely impact any ability the U.S. has to compete in the global industrial and scientific laser market, effectively abandoning our competitive edge to companies in other countries.

These proposed rule changes, if issued, will have a seriously detrimental impact on the U.S. industrial base, effectively harming our national security rather than protecting it. In the 2012 joint Department of Defense and Department of State report to Congress regarding returning commercial satellites to the Commerce Department for export control purposes, the Departments stated that controlling such commercial world-wide available items as military was actually harmful to the national security interests of the United States. It had the unintended effect of weakening the U.S. industrial base while doing nothing to protect the critical technologies required of our military.

Yet, this proposed rule has the potential of repeating this same mistake. It will remove these segments of the U.S. industry from the global market, conceding this market to already established foreign companies, enabling them to grow unchallenged by any U.S. competition. Already strong, competitive companies such as Dali and Wuhan-Guide in China, Ulis and Sofradir in France, Selex in the UK, AIM, Rofin, and Jenoptik in Germany, Le Tehnika in Slovenia, Optec in Italy, SCD in Israel, Hamamatsu and NEC in Japan, Teledyne-Dalsa in Canada, and MikroSens in Turkey will continue to grow with the disappearance of U.S. industry from these well-established commercial markets.

We strongly urge a fundamental rewrite of this proposed rule to categorize these items as commercial items regulated by the Department of Commerce if such similar items are available outside the United States and are also controlled as commercial items. It makes no sense for the United States to control these items as military when similar items manufactured overseas are controlled as commercial. U.S. companies must have the ability to compete on a level footing against foreign competition.

Enabling the global competitiveness of U.S. companies will foster growth, investment in new technology, and strengthen the U.S. industrial base. That will help to ensure a continued stream of advanced technology remains available to our nation, enhancing national security. As evidenced in the commercial satellite field, controlling these items as this rule proposes will have the opposite effect by inhibiting U.S. industry in an already well-established and growing international field.

Should you have any questions in this matter or require additional information, please contact me at (703) 412-0288 or at ghill@drs.com.

Sincerely,

Gregory C. Hill
Vice President
Global Trade Compliance
DRS Technologies, Inc.

Attachments:
1. DRS Specific Comments
2. Sampling of Product Brochures.

Comments regarding specific entries.

1. Note to XII(b)(6), LIDAR and LADAR equipment. The Note to this entry excludes from its control LIDAR systems or equipment for civil automotive applications having a range of 200 meters or less. This means that such systems for civil automotive applications with a range greater than 200 meters will be controlled as defense articles.

The effective range in civil automotive applications is a safety issue. The further the LIDAR or LADAR system is effective, the more time the automotive system has to react. As such, the 200 meter range limitation reduces the safety of such systems in civil automotive applications.

Recommendation: Remove the 200 meter range limit such that the note will reflect that the entry will not control any such LIDAR or LADAR systems that are for civil automotive applications.

2. XII(b)(10), (11), (12), and (13)., tunable, non-tunable, and stacked array lasers. The concern with this entry is that it is absent any positive criteria other than wavelength and power output. Lasers are inherently dual use. The system they are integrated into should define the control, not the laser itself. Additionally, the proposed rule sets the positive criteria for ITAR control at levels well below already fielded international commercial products. For example, the cutoff power density of 3.3 kW/cm^2 is less than half of the foreign commercial availability of almost 8 kW/cm^2. High peak power lasers are available internationally through several international companies. As written, these entries will severely impact any ability the U.S. has to compete in the global industrial and scientific laser market, leaving it to Rofin, Trumpf, and Jenoptik of Germany, who are already market leaders.

Recommendation: Delete XII(b)(10), (11), (12), and (13)

3. XII(c)(2) through (13), infrared focal plane arrays, gimbals, and cryo-coolers.

a. XII(c)(2), un-encapsulated photon detector & microbolometer IRFPAs

b. XII(c)(3), encapsulated One-dimensional photon detector IRFPAs with greater than 640 elements

c. XII(c)(4), encapsulated 2-dimensional photon detector IRFPAs with greater than 256 elements

d. XII(c)(5), encapsulated microbolometer IRFPAs with greater than 328K elements.

e. XII(c)(6), multi-spectral IRFPAs.

f. XII(c)(7) & (8), charge multiplication FPAs.

e. XII(c)(9), integrated dewar cooler assemblies

f. XII(c)(10) & (11), gimbals with 2 or more axes of stabilization better than 200 and 100 micro radians respectively.

g. XII(c)(12), infrared imaging cores

h. XII(c)(13), Binoculars, binoculars, monoculars, etc.

Recommendation: The above entries should be deleted in their entirety. The items they intend to capture as military currently are available from many international sources in countries that all control these items as commercial.

The below lists provide an illustration of the foreign commercial availability of these items. For example, XII(c)(2) proposes to control as military all un-encapsulated microbolometer focal plane arrays. The non-US uncooled infrared detector manufacturers list contains the names of nine (9) companies located in seven (7) countries that design and manufacture these items. All seven (7) countries control these items as commercial/dual-use for exports.

A second example is XII(c)(11) which proposes to control all gimbals with a stabilization better than 100 micro radians as military. The Yiwu TianYing Optical Instrument Company in China sells commercial gimbals with a stabilization of 40 micro radians. These gimbals also contain a 640x512 cooled infrared camera, another item this rule proposes to control as military.

The below lists are by no means complete. The commercial availability is so widespread, there was insufficient time to compile it all. The purpose of these lists is to provide an example of the world-wide commercial availability of most of the items proposed for military control in XII(c).

Additionally, we have attached a sampling of brochures of foreign available equivalent commercial items that are proposed for control here.

<u>Non-US uncooled infrared detector manufacturers:</u>

- Ulis, France, uncooled infrared focal plane arrays up through 1024x768, commercial.
- Semi-Conductor Devices (SCD), Israel, uncooled infrared focal plane arrays up through 640x480, commercial
- NEC Avio Infrared Technologies Co. Ltd., Japan, uncooled infrared focal plane arrays up through 640x480, incorporated into their own commercial IR camera cores and camera systems, commercial
- Wuhan-Guide, China, http://wuhan-guide.com uncooled infrared focal plane arrays up through 640x480, commercial (non-Wassenaar member)
- Zhejiang Dali Technology Co., China, www.ir-thermalimagingcamera.com, uncooled infrared focal plane arrays up through 640 x 480, commercial (non-Wassenaar member)
- Debut Optoelectric Sensor Co, Ltd, China, uncooled infrared focal plane arrays up through 640x480, commercial, (non-Wassenaar member)

- Fraunhofer IMS, Germany, www.ims.fraunhofer.de, uncooled infrared focal plane arrays up through 320x240, commercial
- MikroSens, Turkey, www.mikrosens.com.tr, uncooled focal plane arrays up through 160x120, commercial
- Teledyne-Dalsa, Canada, uncooled infrared focal plane arrays up through 640x480, commercial

Non-US cooled infrared detector manufacturers and products:

- Selex, UK, www.selex-es.com, cooled infrared focal plane arrays up through 1024x768, commercial
- Sofradir, France, www.sofradir.com, cooled infrared focal plane arrays up through 640x512
- Semi-Conductor Devices (SCD), Israel, www.scd.co.il, cooled infrared focal plane arrays up through 1920x1536 (10 micron, mid-wave InSb), commercial.
- Xenics, Belgium, 640 x 512 InGaAs SWIR FPAs, commercial (also designs its own ROICs)

Non-US Read Out Integrated Circuits (ROICs)

Xenics, Belgium,

sInfraRed, Singapore,

Alcatel-Thales, France,

New Imaging Technologies, France

New Infrared Technologies, Spain,

ChungHwa/Leading-Light (Taiwan),

Semiconductor Devices (SCD – Israel),

Mikro-Tasarım, Turkey

Non-US Cryogenic Coolers

AIM, Germany

Le Tehnika, Slovenia

Ricor, Israel

Thales, Netherlands

Infrared Optics

Knight Optical, UK, www.knightoptical.com,

BMV Optical, Canada, http://www.bmvoptical.com/

Success Infrared, China http://www.optics-infrared.com/LenseUC.html

Kunming Yunzhe High-Tech, Ltd, China, www.yzoptics.com/yzgxEnglish/index.html

Gimbals

Beijing Hamilton Technology Co., Ltd China, **hamilton**-tech.company.weiku.com, gimbal with 320x256 cooled MCT (mid-wave) camera, stabilization as ≤0.2mrad(RMS)

Yiwu TianYing Optical Instrument Company, China, http://www.nightvisioncn.com/,

EOST-210 Airborne/UAV/Helicopter Thermal Imaging Camera System- 2 axis 40 micro radian stable accuracy,640x512 uncooled, 40mk NETD, auto tracking

EOST2000M, Maritime search & rescue thermal imaging camera system, 4-axis gyro stability 10 micro radian stabile accuracy, 640x512 cooled, auto tracking

Infrared Hand Helds & Cores

China, Pearmain 384x288, 50 Hz uncooled core, lead time 1 to 7 days. http://pearmain.manufacturer.globalsources.com/si/6008813092486/pdtl/Thermal-imaging/1025737934/Thermal-Camera-Module.htm

China, Dali 384x288, 50 Hz uncooled core, lead time 2-4 weeks (200 units), http://www.ir-thermalimagingcamera.com/sale-2713265-8-14um-ip54-industrial-thermal-imaging-module-for-security-surveillance.html

Taiwan, Allied Scientific Pro either a 640x480 or a 384x288, 60 Hz uncooled core, lead time 2 weeks (up to 1000 units) http://alliedscientificpro.com/shop/uncooled-lwir-infrared-sensor-8-to-14-microns/

4. XII(c)(16)(iii). This entry lists fixed-site reconnaissance, surveillance, and perimeter security missions as the positive criteria. These are not unique to the military and have broad commercial security applications.

Recommendation: Delete entry.

5. XII(c)(18), near-to-eye display systems. This entry intends to control what amounts to a TV screen.

Recommendation: Delete the entry.

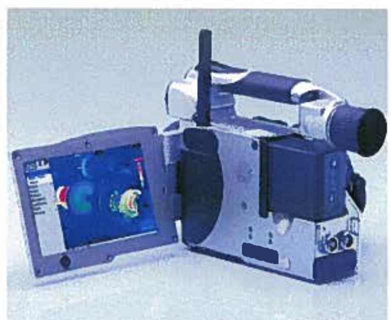
6. XII(e)(3) through (10) and (12) through (14) Wafers, ROICs, Vacuum packages, Integrated Dewar Cooler Assemblies, Cryocoolers, cryostats, infrared lenses, image processing electronics, near-to-eye displays, IR scene projectors.

Recommendation: These entries should be deleted. See the above lists for the wide-spread foreign commercial availability of these commercial items.

JENOPTIK

VarioCAM® HD Thermographic Infrared Cameras

Precision Thermography with up to 2048 × 1536 IR Pixels Resolution



High Definition Infrared made in Germany: Thermographic precision you can rely on.

If demanding thermal imaging is your assignment, the new VarioCAM® HD uncooled thermographic cameras will be your first choice solution.

VarioCAM® HD outputs crisp and most detailed radiometric images of **up to 2048 × 1536 pixel** spatial resolution enabled by Jenoptik's ***Resolution Enhancement technology*** and offers a thermal resolution of **50 mK NETD**. Operating at a frame rate of up to 30 Hz, the camera provides a **real-time** image resolution of **1024 x 768 pixel**.

VarioCAM® HD is the world's first thermography camera featuring a built-in **laser rangefinder** for optimal temperature correction, autofocus support and precise geo-referencing in connection with the **built-in GPS** module. For immediate image control the camera offers a robust and extra-large **1280×800 pixel 5.6" TFT display** and an tiltable viewfinder. Versatile industry-proof standard interface options, including wireless and GigE-Vision allow for easy remote imaging.

Matching a broad variety of thermal imaging applications, a **great choice of high quality infrared optics** is available – of course, also made in Germany, manufactured by Jenoptik.

Applications:

- Industrial and scientific research & development
- Predictive and preventive maintenance
- Building inspection

Sensor Systems

VarioCAM® HD Thermographic Infrared Cameras

Precision Thermography with up to 2048 × 1536 IR Pixel Resolution

Specifications

	VarioCAM® HD 1024 inspect	VarioCAM® HD 1024 research	
Detector type	Uncooled microbolometer (Focal Plane Array)		
Image resolution [pixel]	1024 × 768	2048 × 1536 (RE mode)	1024 × 768
Image rate (@ max. image resolution)	30 Hz	n.s. [2]	30 Hz
Subframe modes & frame rates (optional)	640 × 480 (60 fps) I 384 × 288 (120 fps) I 1024 × 96 (240 fps)		
Spectral range	7.5 µm ... 14 µm		
Temperature measurement range [1]	-40 °C ... +1,200 °C I High temperature option: up to 2,000 °C		
Thermal resolution [NETD]	≤ 50 mK		
Measurement accuracy	± 1.5 K or ± 1.5 %		
Dynamic range	16 bit		
Laser rangefinder	Accuracy: ± 1.5 mm I Range: 70 m I Wavelength: 635 nm (red) I Laser class: 2		
Focus	Laser rangefinder supported autofocus I Passive autofocus I Motorized manual focus		
Display	Extra-large 5.6" color TFT display I 1280 × 800 pixel resolution I Suitable for daylight operation		
Viewfinder	Tiltable LCoS color viewfinder display I 800 × 600 pixel resolution		
Geo-localization	Built-in GPS for geo-referencing		
Digital VIS camera	CMOS color camera I up to 8 Megapixel resolution for image and video recording		
Audio	Integrated microphone and loudspeaker for image annotations		
Image / video storage	SDHC memory card		
Interfaces for image transfer	GigE-Vision I DVI-D I C-Video I WLAN (option)		
Interfaces for camera control	GigE-Vision I RS-232 I Trigger I USB 2.0 I Bluetooth (option)		
Power supply	External: 12 VDC ... 24 VDC I Battery: standard Li-Ion video camera battery		
Operating temperature	-25 °C ... +55 °C (operational)		
Storing temperature	-40 °C ... +70 °C		
Humidity	Relative humidity 10% ... 95%, non-condensing		
Shock	Operational: 25G, IEC 68-2-29		
Vibration	Operational: 2G, IEC 68-2-6		
Protection class	IP54		
Dimensions (with standard 1.0/30 mm lens)	210 mm × 125 mm × 155 mm [L × W × H]		
Weight (with standard 1.0/30 mm lens)	1.7 kg		
Measurement functions (selection)	Multiple measurement spots & ROIs I Hot/cold spot detection I Isotherms I Profiles I Differences		
Automatic functions (selection)	Focus I Image I Level I Range I NUC I Lens recognition I Image optimization I Alarm sequence		
Correction functions	LDC™ - Laser rangefinder based Distance Correction I Emissivity (manual or material table) Transmissivity I Ambient temperature I Humidity (option)		
Available lenses (with IP54-proof bayonet mount)	Super-Wide-Angle: 1.0 / 7.5 mm Wide-Angle: 1.0 / 15 mm Standard: 1.0 / 30 mm Telephoto: 1.0 / 60 mm Super-Telephoto: 1.0 / 120 mm	HFOV × VFOV, and minimum focus distance: 98° × 82° 100 mm 60° × 47° 200 mm 32° × 24° 300 mm 16° × 12° 2,000 mm 8° × 6° 4,000 mm	

[1]) Overall range available for measurement and visualization. Four discrete sensitivity levels are used.
[2]) Single frame acquisition mode only. Frame rate for RE image series not specified yet. Live image refresh rate: 30 Hz.

JENOPTIK

JENOPTIK I Defense & Civil Systems
ESW GmbH - Sensor Systems
Pruessingstrasse 41 I 07745 Jena I Germany
Phone +49 3641 65-3942 I Fax -3494
infraredtechnology.dcs@jenoptik.com
www.jenoptik.com/infraredtechnology

Sales North / South Americas
JENOPTIK Advanced Systems, LLC
16490 Innovation Drive I Jupiter FL 33478 I USA
Phone +1 561 881-7400 ext. 1230 I Fax +1 561 88-1947
jdi.sales@jenoptik-inc.com

025007-004-001-04-99-14-0913-en

UMTI Portable Surveillance Thermal Camera 160x120

FOB Price: To be determined

Introduction: Light weight monocular surveillance camera

Contact Supplier

Specifications

Portable Design, easy to operate
Build-in video-recording system (MP4 format)
General purpose rechargeable battery (Lithium Battery)
MIL-STD-810 standard encapsulation for harsh environments

Thermal Vision	
Detector Type	UFPA
Detector Scale	384×288
Spectral Range	8~14 um
NETD	≤80mk
FOV	12°x9°
Focus Range	10m~∞
Digital Zoom	2x
System Feature	
Control Mode	Control Key
Brightness/Contrast Control	Manual/Auto
Image Output Mode	View Finder/Video output
Storage	~20,000 images~1 hour video (with 2G storage spac e)
Viewfinder	High-resolution Gray Scale OLED, monocular
Video Output	PAL(or NTSC)
Power Supply	Li-Ion Rechargeable battery
Rated Voltage	7.2V
Power Consumption	<4W
Battery Operation Time	>3 hr
Start-up Time	<20s
Dimensions	188x94x80mm
Weight	650 g
Detection Range	
Human/meter	1125
Vehicle/meter	3450
Identify Range	
Human/meter	112

Vehicle/meter	345
Encapsulation	
Mil-spec	MIL-STD-810

THE OTHER PRODUCTS OF THIS SUPPLIER

YRH600 Explosion-proof thermal camera 384x288

Hotfind L-R Industrial Thermal Camera 384x288 IP54

E8-N/TN/GN Entry Level Thermal Camera 160x120 Portable 3"LCD

Guangzhou SAT Infrared Technology Co., Ltd.

Nico Chung

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NV618W Automobile Safety Driving Assistant System

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SEARCH

PRODUCTS

HYPERSPECTRAL IMAGING CAMERAS

- >Hyper-Cam
- >Hyper-Cam Methane
- >Airborne Platform
- >Reveal D&I
- >Motorized Polarizer Module

INFRARED CAMERAS

- >TS-IR Thermal Scientific IR Camera
- >HD-IR 1280 High Definition IR Camera
- >FAST-IR Rapid IR Camera
- >HDR-IR High Dynamic Range IR Camera
- >MS-IR Multispectral IR Camera

HDR-IR High Dynamic Range IR Camera

The HDR-IR high dynamic range infrared camera series includes high performance cameras which cover extended scene temperature ranges.

These cameras maximize camera sensitivity automatically for any static or dynamic scenes. They find the best exposure time according to the scene and allow to resolve targets up to 2500°C.

Key Benefits

- Ultra-high dyanmic range ensure observation of scene targets with extremely high contrast and acc
- Real-time radiometric or uniformity corrected images
- Patent black body free correction technique
- Thermal sensitivity allows to detect temperature différences as small as 20 mK

DETECTOR SPECIFICATIONS

Click on the product name to download the datasheet.

	HDR-IR MW	HDR-IR VLW	HDR-IR HD InSb	HDR-IR HD MCT	HDR FAS
Detector type	MCT	MCT	InSb	MCT	InSb
Spectral range	3 µm to 4.9 µm	7.7 µm to 11.8 µm	3 µm to 5 µm	3.7 µm to 4.8 µm	3 µm to
Spectral resolution	640 x 512 pixels	320 x 256 pixels	1280 x 1024 pixels	1280 x 1024 pixels	320 x 25
Detector Pitch	16 µm	30 µm	15 µm	15 µm	30 µ
Aperture size*	f/4	f/2	f/3	f/3	f/2.4
Sensor cooling	Rotary-stirling closed cycle	Rotary-stirling closed cycle	Rotary-stirling closed cycle	Split-stirling closed cycle	Split-stirlin cycl

*Other configurations available upon request

TYPICAL PERFORMANCES

	HDR-IR MW	HDR-IR VLW	HDR-IR HD InSb	HDR-IR HD MCT	HD F
Maximum full frame rate	115 Hz	300 Hz	105 Hz	50 Hz	15
Scene temperature range	Up to 2500°C				
Measurement accuracy	1 K or 1 % (°C) 2% (°C) with scene temperature <150°C				
NETD	20 mK	25 mK	22 mK	25 mK	25

ELECTRONIC SPECIFICATIONS

	HDR-IR MW	HDR-IR VLW	HDR-IR HD InSb	HDR-IR HD MCT	HDR FAS
Exposure time	0.2 µs to full frame rate	0.5 µs to full frame rate	0.5 µs to full frame rate	16 µs to full frame rate	1 µs to ful rate

All Products
- IR Thermal Imaging Camera (34)
- Night Vision Thermal Imaging Camera (24)
- Handheld Thermal Imaging Camera (12)
- Uncooled Infrared Detectors (4)
- Thermal Imaging Module (6)
- Industrial Thermal Imager (14)
- Fixed Thermal Imaging Camera (20)
- Remote Thermal Imaging Camera (7)
- Long Distance Security Cameras (18)
- Thermal Security Camera (24)
- CCTV Surveillance System (17)
- Firefighter Thermal Imaging Camera (3)
- Vehicle Thermal Imaging Camera (3)
- Gas Detection Camera (3)

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Auto / Manual IP67 Thermal Imaging Binocular For Hunting / Marine Navigation

Large Image : Auto / Manual IP67 Thermal Imaging Binocular For Hunting / Marine Navigation

Product Details:

Place of Origin:	**Zhejiang, China (Mainland)**
Brand Name:	**DALI**
Certification:	**CE**
Model Number:	**S750M**

Payment & Shipping Terms:

Minimum Order Quantity:	**1**
Packaging Details:	**basis on incasement request**
Delivery Time:	**2-4 weeks**
Payment Terms:	**L/C,T/T**
Supply Ability:	**200 Unit/Units**

Submit Quote Now

Detailed Product Description

Auto / Manual IP67 Thermal Imaging Binocular For Hunting / Marine Navigation

Quick Detail:

Place of Origin: Zhejiang, China (Mainland)
Brand Name: DALI
Model Number: S750M
Usage: Security
Theory: Infrared Thermometer
Detector type: Un-cooled FPA micro-bolometer
Array size: 384X288
Lens option: 61mm, Auto focus
Thermal sensitivity: ≤0.08°C@30°C
Frame frequency: 50Hz
Focus: auto/manual
Zoom: X2
Spectral range: 8-14um
Encapsulation: IP67
Photo and Record
GPS electronic compass
Laser range finder

Description:

S750M is portable, handheld thermal imaging binocular observation equipment for day and night searching and observation, has photo and record functions. With features of anti-shock and vibration, enjoys wide operating temperature range and other characteristics, used in the fields of night vision observation and surveillance, security smuggling, criminal investigation, search and rescue and other fields.

Applications:

Marine navigation
Personal security
Border surveillance
Hunting
Law enforcement

Technical specification

Items		S750M
Detector	Detector type	Uncooled FPA microbolometer
	Spectral range	8 ~ 14 μm
	Array size	384×288
	Pixel size	25μm
Machine Characteristics	NETD	≤80mk@30℃
Lens	Lens	61mm/F0.8
	Fov	9.0°×6.75°(±5%)
	Brightness enhancement	Auto/Manual
	Image enhancement	Yes
	Filtering	Yes

Information Machine	Laser range finder	Working band	1.55 μm(safe for human eye)
		Distance	20m~2Km
		Accuracy	≤2m
		Range	≤30m
		Success Rate	≥96%
		Working frequency	3/minute(urgency 10/minute)
	Target location accuracy	±2m(within1Km), ±5m(1Km-2Km)	
Environment	Operating temp	-20℃~+50℃(Standard)	
		-40℃~+60℃(Specially Made)	
	Storage temp	-40℃~+60℃(Standard)	
		-40℃~+65℃(Specially Made)	
	Encapsulation	IP67	
Power System	Battery type	Li-Ion, rechargeable	
	Battery operating time	3 hours continuous working,range detection of 100 times(at normal temperature)	

Contact Details

ZHEJIANG DALI TECHNOLOGY CO.,LTD
Contact Person: **Mr. Steve**
Tel:**86-571-86695666**
Fax:**86-571-86695600**

Send your inquiry directly to us

Please enter the inquiry details, such as product name, color, size, MOQ, FOB, etc.

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Other Products

- Industial LT3 IR Thermal Imaging Camera With 2m Drop Resistant
- Law Enforcement Applicat Thermal Imaging Binocular , Lightweight Thermal Imaging Cameras
- Waterproof Ultra - Compact Thermal Imaging Camera For Home Inspection
- Portable IR Thermal Imaging Camera S930H , Thermal Imaging Binocular For Security
- Handheld IP54 LT7-P IR Thermal Imaging Camera , Firefighter Thermal Imaging Camera
- Fusion Display IR Thermal Imaging Camera With 3.6" Touch Screen

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IR Thermal Imaging Camera
- Auto Gas Detection IR Thermal Imaging Camera , Industrial Thermal Imager For Insulation Failure
- Parking Pot IR Thermal Imaging Camera , Industrial Thermal Imager
- Industrial IP67 IR Thermal Imaging Camera For Component Detective

Night Vision Thermal Imaging Camera
- CCD Visual Night Vision Thermal Imaging Camera , Infrared Thermal Imager With PTZ
- Double Visual IR Thermal Imaging Camera , CCTV Security Systems
- Online Industrial Night Vision Thermal Imaging Camera , Box Video Camera

Handheld Thermal Imaging Camera
- Fire Rescue Handheld Thermal Imaging Camera With Temperature Measurement Function
- Waterproof Digital Handheld Thermal Imaging Camera , 3.6" Touch Screen
- Lightweight Un - cooled IP54 Handheld Thermal Imaging Camera , 160*120

Contact Us
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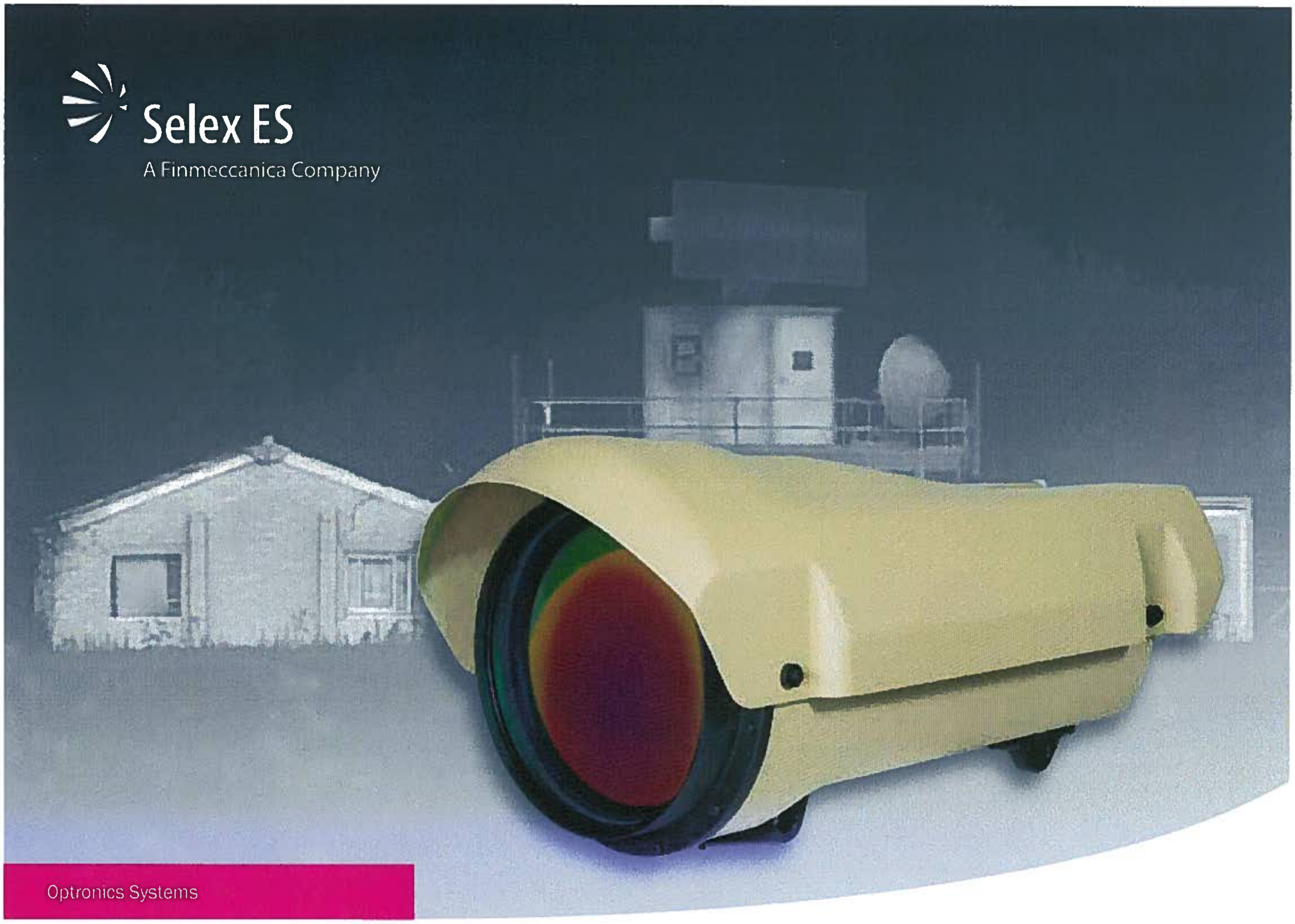
China good quality IR Thermal Imaging Camera supplier.



HORIZON SD/HD
THERMAL IMAGING CAMERA

The Horizon Medium Wave Infra-Red (MWIR) thermal imaging camera employs the latest focal plane array technology to meet long-range surveillance and target identification requirements.

Utilising a modular Integrated Detector Cooler Assembly, the camera is fitted with either Standard Definition (SD) or High Definition (HD) detector arrays. This design allows for rapid assembly and ease of maintenance.

Horizon HD provides a wider Field of View (FoV) for greater Situational Awareness, whilst delivering a narrower IFoV for longer range target identification and engagement.
Horizon cameras have been specifically designed with very long life cooling engines of 50,000 hours. This increases reliability and reduces through-life costs.

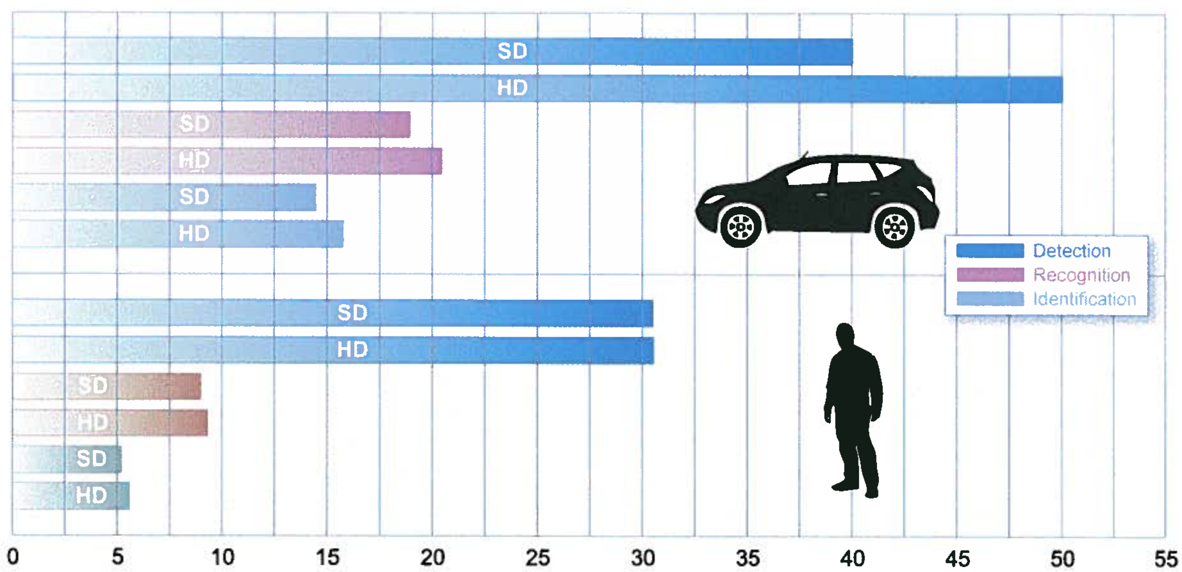
KEY BENEFITS

- Designed, developed and manufactured in the UK
- 'Dual Use' rated
- Very low through-life cost - 50,000 hours cooling engine life
- Ease of integration – video and communication over Ethernet
- Multiple digital and analogue video outputs
- ONVIF control and video interface
- Latest image processing
  - Turbulence mitigation
  - Image stabilisation
  - Local area contrast enhancement
- Ultra narrow field of view: 0.6°
- Qualified to operate from -40°C to +55°C
- Extended warranty options
- Finance options available
- Service provision contracts options

The Camera that Sees Further than You Can

TECHNICAL SPECIFICATION

Detector array resolution	640 x 512 (SD), 1280 x 720 (HD)
Detector pitch	16μm (SD), 12μm (HD)
FOV	7.3 x 5.9 degrees to 0.6 x 0.5 degrees (SD) 11.0 x 6.2 degrees to 0.9 x 0.5 degrees (HD)
Detector technology	CMT
Band	3.7μm - 4.95μm
F/Number	F/4
Focal length of continuous optical zoom	80-960mm
Comms	RS-422 Ethernet
Analogue video output	NTSC PAL (CCIR) HDTV 720p
Digital video output	HD-SDI Ethernet (H264, ONVIF)
Operating temperature	-40°C to 55°C
Weight	23kg
Size (L x W x H)	596.5mm x 299mm x 299mm
Power source	28VDC (18-32V)
Nominal power at steady state	<25W
Dynamic range enhancement	LACE Linear Edge enhancement
Image stabilisation	Yes
Turbulence mitigation	Yes
Auto focus	Yes
Cooling engine	Long life linear (50,000hrs)
Non-uniformity corrector	Built-in reference and quadratic NUC
E-Zoom	Interpolated (up to 8x)



For more information please email infomarketing@selex-es.com
Selex ES Ltd - A Finmeccanica Company
Southampton First Avenue - Millbrook Industrial Estate - Southampton - Hampshire - SO15 OLG - Tel: +44 (0) 2380 702300

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Cooled Long Distance Fixed Thermal Imaging Camera For CCTV Surveillance

Large Image : Cooled Long Distance Fixed Thermal Imaging Camera For CCTV Surveillance

Product Details:

Place of Origin:	**Zhejiang, China (Mainland)**
Brand Name:	**DALI**
Certification:	**CE**
Model Number:	**DLD-M600**

Payment & Shipping Terms:

Minimum Order Quantity:	**1**
Packaging Details:	**basis on incasement request**
Delivery Time:	**2-4 weeks**
Payment Terms:	**L/C,T/T**
Supply Ability:	**200 Unit/Units**

Submit Query

Detailed Product Description

Cooled Long Distance Fixed Thermal Imaging Camera For CCTV Surveillance

Quick Detail:

- ◆ 600mm focal length, ultra long-range observation distance
- ◆ 15KM vehicle/30KM medium vessel security detection
- ◆ Triple FOV, meets the different requirement of detection ,recognition, identification
- ◆ FOV switch time <1S
- ◆ Digital Detail Enhancement(DDE)
- ◆ Multiple user defined auto mode , meets different targets observation require ment in different environment.
- ◆ RS422 remote control
- ◆ Rugged housing,compact structure,high protection encapsulation(IP67)

Applications:

Suitable for border, maritime, ports and islands where require day and night security surveillance.

Technical specification:

Item		**Specification**	
Detector	Detector type	HgTeCd Cooled FPA detector	
	Array size/format	320×256	640×512
	Pixel pitch	30μm	15μm
Image characteristics	Field of view(FOV)	WFOV: 11°×8.8° MFOV: 2.2°×1.76° NFOV: 0.92°×0.73°	
	Focal length	50/250/600mm	
	Spatial resolution	WFOV:0.6mrad MFOV 0.12 mrad NFOV 0.05mrad	
	FOV switch time	≤1s	
	NETD	≤35mk@30℃,F4	
	Frame frequency	50Hz	
	Focus	Auto/Electrical manual focus	
	Spectral range	3.7~4.8μm	
Thermal operation	Starting time	<8min(In normal temperature 25 degrees)	
	Brightness/gain adjustment	manual brightness/gain adjustment; auto brightness/gain adjustment	
	auto brightness/gain configuration adjustment	2 fix pattern,8 user defined setting pattern	
	Polarity reversal	Black hot/White hot	
	Zoom	2x	
	Noise reduction	Yes	
	DDE	Yes	
	Calibration	Automatic and manual calibration	
	Crosshair	Display/Hidden	
Power system	External power supply	24±3V DC	
	Power consumption	<14W(In normal temperature 25℃ normal work)	
Environment	Operating temperature	-40℃~ +55℃	
	Storage temperature	-45℃~+65℃	
	Encapsulation	IP67	
Physical	Weight	≤7Kg	

Contact Details

ZHEJIANG DALI TECHNOLOGY CO.,LTD
Contact Person: **Mr. Steve**
Tel:**86-571-86695666**
Fax:**86-571-86695600**

Send your inquiry directly to us

Please enter the inquiry details, such as product name, color, size, MOQ, FOB, etc.

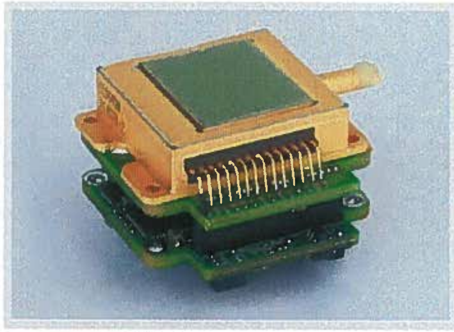
(0 / 3000)

Submit Query

Other Products

- Long Distance Fixed Thermal Imaging Camera For Residential District , IP67
- Remote Control Fixed Thermal Imaging Camera , Online Dual FOV Monitoring System
- Waterproof CCTV Surveillance Fixed Thermal Imaging Camera With Night Vision
- Temperature Measurement Thermal Imaging Security Camera With 24/7 Monitoring
- Multi - interface Thermal Imaging Camera , Auto / Electri Infrared Thermal Imager
- Wifi Night Vision Thermographic Camera For Surveillance System

Manual Portable Thermal Imaging Module , 640X480 Thermal Camera Module



Large Image : Manual Portable Thermal Imaging Module , 640X480 Thermal Camera Module

Product Details:

Place of Origin:	**Zhejiang, China (Mainland)**
Brand Name:	**DALI**
Certification:	**CE**
Model Number:	**D840**

Payment & Shipping Terms:

Minimum Order Quantity:	**1**
Packaging Details:	**basis on incasement request**
Delivery Time:	**2-4 weeks**
Payment Terms:	**L/C,T/T**
Supply Ability:	**200 Unit/Units**

Submit Query

Detailed Product Description

Manual Portable Thermal Imaging Module , 640X480 Thermal Camera Module

Quick Detail:

Place of Origin: Zhejiang, China (Mainland)
Brand Name: DALI
Model Number: D880
Usage: Security
Theory: Infrared Thermometer
Detector type: Un-cooled FPA micro-bolometer
Array size: 640X480
Pixel size:17μm
Thermal sensitivity: ≤60mK(f/1,300K,25-50Hz)
Temp control: TEC
Digital zoom: 2X,3X,4X
Power consumption: ≤2W(normal atmospheric temp)
Frame frequency: 50Hz

Description:

DALI detector contributes to high price & performance ratio
Small size & Low weight, multiple interface, easy for your integration
High resolution, good image quality
Low consumption for longer continuation
Pseudo color optional for your easy observation
Low and wide voltage power supply,0.5V~5V
Wide operational temperature extended to -40℃~ +60℃

Applications:

Marine navigation
Personal security
Border surveillance
Hunting
Law enforcement

Technical specification:

		D840
Detector characteristics	Detector type	Uncooled FPA microbolometer
	Array size	640X480
	Pixel	17um
	Spectral range	8~14um
	Temp control	TEC
	NETD	≤60mK(f/1,300K,25-50Hz)
	Thermal time constant	≤5ms
	Frame rate	50Hz
	Display resolution	640x480

Environment	Operation temperature	-15℃~ +50℃ (Can expanded to -40℃~ +60℃)
	Storage temperature	-40℃~ +70℃
	Humidity	5~95%,Non condensing
physical characteristics	Size(mm)	W40mm× H41mm× D35mm
	Weight	≤76g(including housing,shutter)
	Lens mount interface	M34×0.75 ;screw thread
	Mechanical interface	2×M3(four sides);screw hole
	Electrical connector	26 pins connector(including cable)

Competitive Advantage:

◆ Extremely compact and extremely light
◆ Image capture and recording




Contact Details

ZHEJIANG DALI TECHNOLOGY CO.,LTD
Contact Person: **Mr. Steve**
Tel:**86-571-86695666**
Fax:**86-571-86695600**

Send your inquiry directly to us

Please enter the inquiry details, such as product name, color, size, MOQ, FOB, etc.

(0 / 3000)

Submit Query

Other Products

- Small Size OEM Thermal Imaging Module For System Integration , 384X288
- Low Power Consumption Un - cooled Thermal Imaging Module For Hunting
- Universal Un - cooled Infrared Thermal Imaging Module For Coastal Defense
- Lightweight Thermal Imaging Cores For Port security , Thermal Imaging Camera Module
- 8-14um IP54 Industrial Thermal Imaging Module For Security Surveillance

All Products

- IR Thermal Imaging Camera (34)
- Night Vision Thermal Imaging Camera (24)
- Handheld Thermal Imaging Camera (12)
- Uncooled Infrared Detectors (4)
- Thermal Imaging Module (6)
- Industrial Thermal Imager (14)
- Fixed Thermal Imaging Camera (20)
- Remote Thermal Imaging Camera (7)
- Long Distance Security Cameras (18)
- Thermal Security Camera (24)
- CCTV Surveillance System (17)
- Firefighter Thermal Imaging Camera (3)
- Vehicle Thermal Imaging Camera (3)
- Gas Detection Camera (3)

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High Resolution Uncooled Infrared Detectors With Completely Independent Core Technology , 640*480

Detailed Product Description

High Resolution Uncooled Infrared Detectors With Completely Independent Core Technology , 640*480

Quick Detail:

Place of Origin: Zhejiang, China (Mainland) Brand Name: DALI
Model Number: DLC640/DLD640
Usage: Security
Detector type: Un-cooled FPA micro-bolometer
Array size: 640X480 Pixel pitch: 25um/17um
Spectral range: 8-14um Frame frequency: 25~50Hz
Thermal sensitivity: ≤60mk@(f/1;300k)

Description:

The Uncooled Microbolometer infrared FPA detector researched and developed by Dali has already been applied in industrial production. It has the advantages of high resolution, high sensitivity, low fixed pattern noise and fast response.Detector is manufactured in Standard MIL STD810/813, applicable to different industry.

Specifications:

Item	DLC640/DLD640 (25μm / 17μm)
Material	amorphous silicon
Array size	640×480
Pixel pitch	25μm / 17μm
Fill factor	≥60%
Spectral range	8-14μm
Temperature control	TEC
Frame rate	25Hz single / 50Hz double end
NETD	≤60mK(f/1,300K,25-50Hz)
Thermal time constant	≤5ms
Responsivity	≥8mV/K
Operability	≥99%
Power supply	5V
Power consumption	≤300mW(excluding TEC)
Output	single / double end
Dimension	32mm×23.5mm×7.6mm(pin is not included)
Weight	≤20g
Operating temperature	-40°C - +60°C
Storage temperature	-40°C - +85°C
Standards	MIL-STD-810 and -883

Competitive Advantage:

- Different resolution
- Short integral time
- Stable performance in temperature range -40℃ to +60℃
- Extremely low thermal noise
- Excellent nonuniformity

Contact Details

ZHEJIANG DALI TECHNOLOGY CO.,LTD
Contact Person: **Mr. Steve**
Tel:**86-571-86695666**
Fax:**86-571-86695600**

Send your inquiry directly to us

Please enter the inquiry details, such as product name, color, size, MOQ, FOB, etc.

(0 / 3000)

Submit Query

Other Products

- High Sensitivity Uncooled Infrared Detectors For Temperature Measurement
- FPA Amorphous Silicon Stable Uncooled Infrared Detectors For Online Monitoring
- Industrial Uncooled Infrared Detectors , Security Thermal IR Camera

About Us
- Company Profile
- Factory Tour
- Quality Control

IR Thermal Imaging Camera
- Auto Gas Detection IR Thermal Imaging Camera , Industrial Thermal Imager For Insulation Failure
- Parking Pot IR Thermal Imaging Camera , Industrial Thermal Imager
- Industrial IP67 IR Thermal Imaging Camera For Component Detective

Night Vision Thermal Imaging Camera
- CCD Visual Night Vision Thermal Imaging Camera , Infrared Thermal Imager With PTZ
- Double Visual IR Thermal Imaging Camera , CCTV Security Systems
- Online Industrial Night Vision Thermal Imaging Camera , Box Video Camera

Handheld Thermal Imaging Camera
- Fire Rescue Handheld Thermal Imaging Camera With Temperature Measurement Function
- Waterproof Digital Handheld Thermal Imaging Camera , 3.6" Touch Screen
- Lightweight Un - cooled IP54 Handheld Thermal Imaging Camera , 160*120

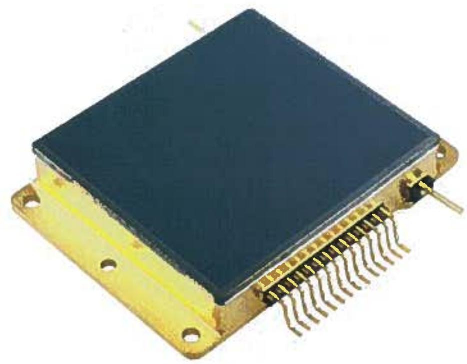
Contact Us
- Contact Info
- Request A Quote
- E-Mail
- Sitemap

China good quality IR Thermal Imaging Camera supplier.

Thermal image sensors

17 µm

Gen2



PICO1024-048

Pico*1024 Gen2* ™

1024 x 768

Military

Surveillance & Security

Thermography

ULIS

Infrared for you

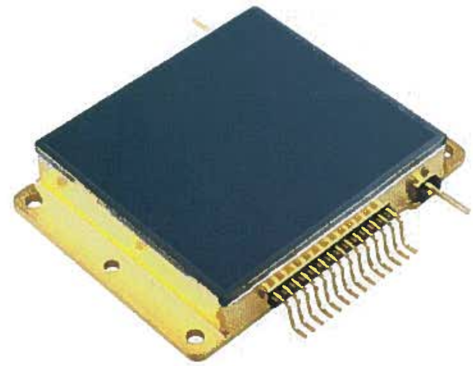
www.ulis-ir.com

PICO1024-048

Pico1024 Gen2™

1024 x 768 - 17 µm

High performance, high definition infrared imaging



PERFORMANCE

- NETD < 50 mK (F/1, 300K, 30Hz)
- Frame rate up to 120Hz
- Typical array operability > 99.9%
- Low power consumption < 210 mW
- Extended operating temperature range: - 40 °C to + 85 °C
- Standards: MIL-STD-810 and -883
- Over exposure / Sun safe

FEATURES

- Material: resistive amorphous silicon
- Spectral response: 8 - 14 µm
- Readout configuration driven by serial link
- Overall dimension (mm): 41.2 x 30 x 6.6 pin out excluded
- Weight < 30 g
- Easy TEC-less implementation

- **High resolution, high contrast imaging for long range detection**
- **Robust for extreme environments (e.g. TWS, RWS, situation awareness, UGS)**
- **Detects fast moving objects**
- **Reduced calibration time**
- **24/7 surveillance capable**
- **Footprint compatible with UL05251-026**

ULIS IN BRIEF

- A unique business model designed to serve OEMs
- High production capacity
- High-performance and cost-effective products
- Guaranteed product availability
- Customer partnership to assure success
- A dedicated customer support team

ULIS
Infrared for you

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www.ulis-ir.com - ulis@ulis-ir.com

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ISO 9001
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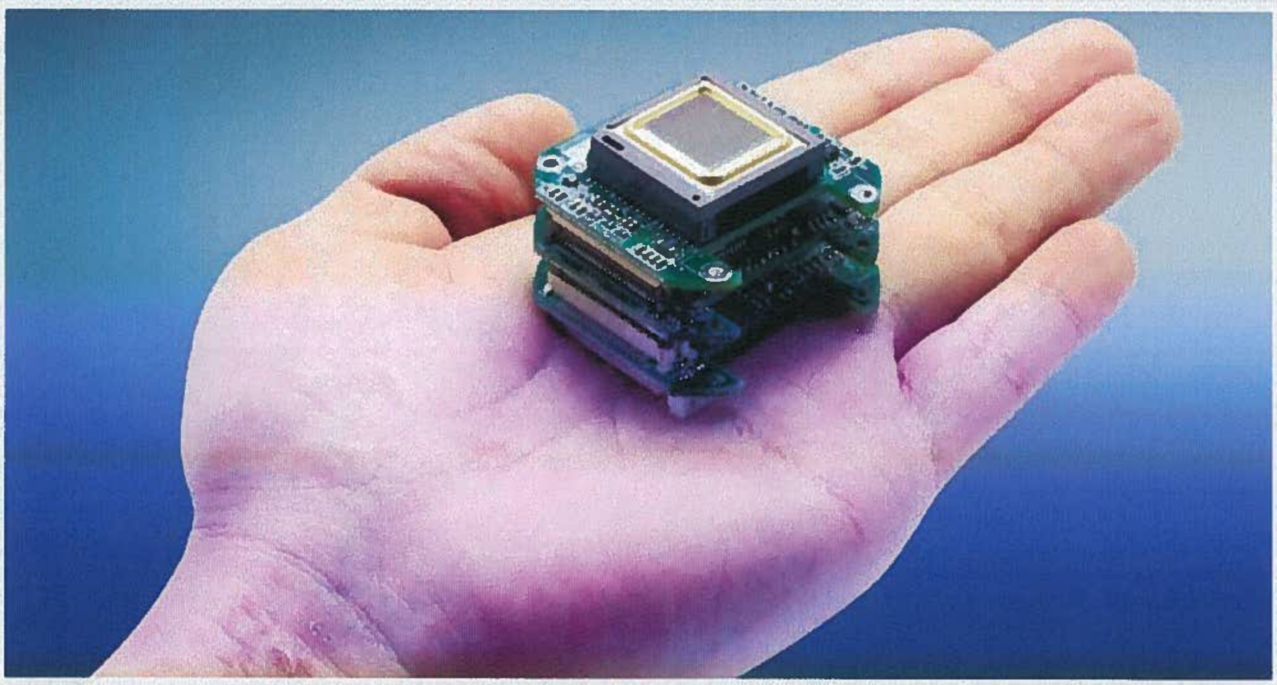
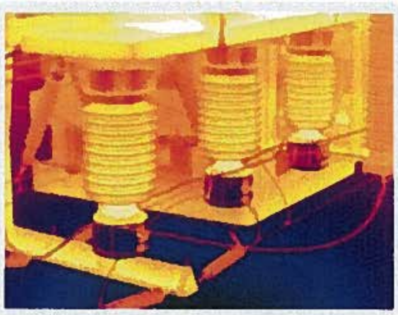
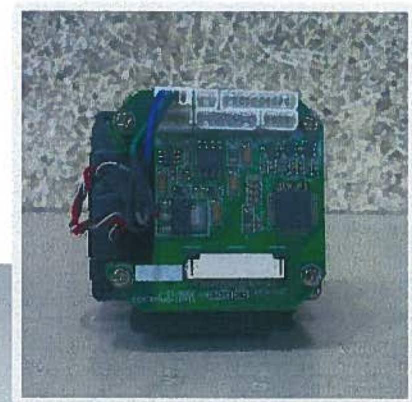
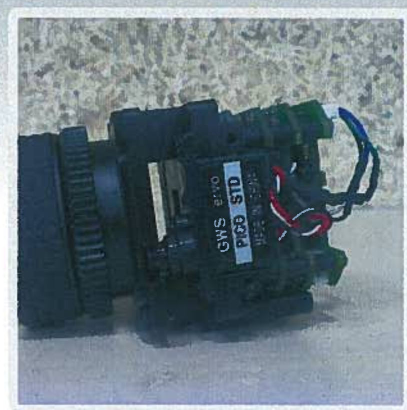
Groupe SOFRADIR












UnCooled LWIR Infrared sensor (8 to 14 microns)

From: $1,380

Core model Choose an option...

Lens Choose an option...

Quantity Choose an option...

3 types:

- ASP-HR160 160 x 120
- ASP-HR320 384 x 288
- ASP-HR640 640 x 480

None ITAR, exportable

More informations

Categories: 8 to 14 microns LWIR, Biology & Microscopy, Defence & Security, Microbolometer. Tags: custom, infrared sensor, swir camera, uncooled, VS Tech lens.

Question? Chat or call here now!

Description **Additional Information**

Reviews (0)

Product Description

From our offices in Canada and Taiwan R.O.C. (Republic of China) we offer uncooled IR imaging modules from 8 to 12 microns.

These sensors are highly responsive and have been adapted for a wide range of applications. The sensor can be purchased either on it's own or with a multitude of different lenses.

The high frame rate output (60Hz @ NTSC or 50Hz @ PAL) enables greater image quality for a wide range of applications than does that of other companies' models.

32 bit SDK available.

We offer the following modules:

- Uncooled Thermal Module(640×480)
- Uncooled Thermal Module(384×288)
- Uncooled Thermal Module(160×120)

HR320 Core Manual

More informations

Need a Germanium Lens design and assembly?

Standard Germanium Optical Lens

Resolution
The camera cores vary in size enabling the customer to choose the most suitable type according to their own requirements.

Compact, light and tiny
The camera core is about 50g (not including lens) and exceptionally small facilitating target integration.

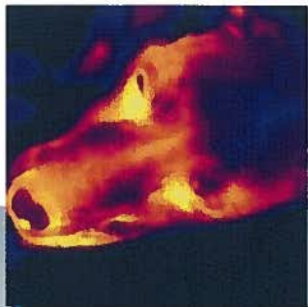
Control functions
Parameters, including brightness, contrast, auto-gain can be set by the user. The customer can also establish parameters via the RS232 interface.

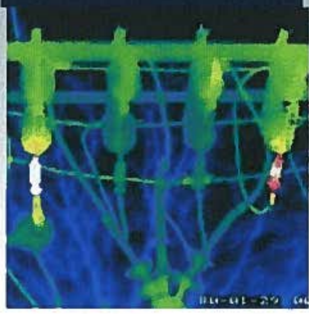
Digital zoom
Our camera core has 2X/4X zoom function. Digital zoom will be of great help when the target is too small to identify.

NTSC & PAL video output
We supply PAL or NTSC, 16-bit parallel digital signal or analog signal. Video format must be specified at time of order.

Contact Us for more details or to get an official quote.

Application Images:



Specifications

Type	ASP-HR160	ASP-HR320	ASP-HR640
	Imaging Performance		
Detector Type	FPA, Uncooled Microbolometer		
Resolution	160 x 120	384 x 288	640 x 480
Spectral Range	8-14 um		
Thermal Sensitivity	80mK @ 300K	50mK @ 300K	60mK @ 300K
Field of View	Lenses are optional, FOV varies according to different lenses		
Focus	Manual/Automatic		
Image Frequency	60 Hz @ NTSC or 50 Hz @ PAL		
	Image Presentation		
Video Output	PAL or NTSC, 14-bit parallel digital signal or analog signal. Video format must be specified at time of order.		
	Power		
Working Voltage	DC 7 – 12 V		

Power Consumption	< 2W	<2.5 W	< 3 W
	Environmental Specifications		
Operating Temperature Range	-40°C to 60°C		
Storage Temperature Range	-40°C to 70°C		
Humidity	<95%, non-condensing		
	Physical Characteristics (without lens, core only)		
Size (L x W x H)	40 mm x 40 mm x 30 mm		45 mm x 45 mm x 37 mm
Weight	50g		
	Interface		
RS232	Command and Control Functions		

Applications:

- Thermology
- Thermal Imaging for Automation
- Night Vision
- Surveillance
- Security of Nuclear Plan
- Law Enforcement
- Infrared Camera for Building Diagnostics
- Automotive Night Vision
- Aviation and Maritime Enhance Vision
- Electrical and Mechanical Thermal Imaging
- Thermal Imaging for Gas Detection
- Furnace and Boiler Inspection
- Medical/Biology
- Maritime
- Power plants
- Metal Production
- Petrochemicals

WDR InGaAs Product Range

Description

For laser measurements, high temperature thermography, Coastal surveillance, bio medical imaging, waste sorting...

NIT introduces his new **WDR InGaAs products family**, including **sensors and camera modules**.

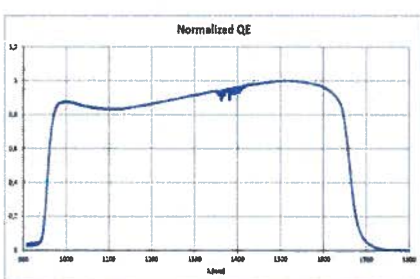
NIT Short Wave Infrared (SWIR) products are based on a proprietary **Wide Dynamic Range ROIC technologies** and offer a **Dynamic Range (DR) of more than 140dB in a single image without any external control.**

The internal Fixed Pattern Noise correction gives a **high uniformity pcitures in all light conditions** with no need of Look-up table.

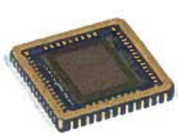
The NIT WDR InGaAs sensors use **InGaAs photodiodes array** operating **from 900nm up to 1700nm** with a high QE and coupled to a patented Read Out Circuit (ROIC).

The camera modules, WiDy SWIR family, offer different interfaces compatibility with an exterme ease of use :

- The **digital version** are delivered with a full Software development kit (SDK), WiDy View, operating under Microsoft Windows.
- The **analog version** gives direct SWIR video flux through composite connection.



Spectral response



WDR InGaAs Sensors Family

White papers & Application Notes

- Native WDR™ Technology : Novel Wide Dynamic Range CMOS imagers.
- ESSCIRC 2001 - A CMOS Image sensor with on-chip FPN compensation
- Native WDR™ Sensor Technology for Welding Applications
- DSS SPIE 2011 : Wide Dynamic Range ROIC & InGaAs for SWIR imaging
- ISW2011 - Native WDR Sensor Technology

	Resolution	Pixel Size (µm²)	Optical Format	Frame Rate	Dynamic Range	Trigger In/Out	Output	Related Documents
NSC0803-SI	320 x 256	25x25	2/3"	150fps	140 dB	Rolling	Analog	On request
NSC1101-SI	640 x 512	15x15	1"	60fps	140 dB	Rolling	Analog	On request
NSC1201-SI	640 x 512	15x15	1"	60fps	140 dB	Snapshot	Analog	On request

WDR InGaAs Modules Family

Camera	Resolution	Output	Frame Rate	ADC	Operation Mode	Dynamic Range	Trigger In/Out	Software	Related Documents
WiDy SWIR 320A	320 x 256	Analog TV	50/60fps	--	Rolling shutter	140 dB	--	--	On request
WiDy SWIR 320U	320 x 256	USB 2.0	140fps	14 bit	Rolling shutter	140 dB	Trigger In/Out	WiDy View SDK	On request
WiDy SWIR 640U	640 x 512	USB 2.0	60fps	14 bit	Rolling shutter	140 dB	Trigger In/Out	WiDy View SDK	On request
WiDy SWIR 640A	640 x 512	Analog TV	50/60fps	--	Rolling shutter	140 dB	--	--	On request

See a video on our WiDy Swir

More information

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ROIC Products

			
MT6425CA **CTIA ROIC** 640x512 format 25μm pixel pitch Si, InGaAs, MCT	**MT6415CA** **CTIA ROIC** 640x512 format 15μm pixel pitch Si, InGaAs, MCT	**MT12815CA** **CTIA ROIC** 1280x1024 format 15μm pixel pitch Si, InGaAs, MCT	**MT3825BA** **μBolometer ROIC** 384x288 format 25μm pixel pitch Resistive Pixels
MT6425DA **DI ROIC** 640x512 format 25μm pixel pitch InSb, QWIP, MCT, T2SL	**MT6415DA** **DI ROIC** 640x512 format 15μm pixel pitch InSb, QWIP, MCT, T2SL	**MT12815DA** **DI ROIC** 1280x1024 format 15μm pixel pitch InSb, QWIP, MCT, T2SL	**MT3817BA** **μBolometer ROIC** 384x288 format 17μm pixel pitch Resistive Pixels
MT6420DDA	**MT6410DA**	**MT12810DA**	**MT6417BA**

Dual-DI ROIC 640x512 format 20µm pixel pitch InSb, QWIP, MCT, T2SL	**DI ROIC** 640x512 format 10µm pixel pitch InSb, QWIP, MCT, T2SL	**DI ROIC** 1280x720 format 10µm pixel pitch InSb, QWIP, MCT, T2SL	**µBolometer ROIC** 640x480 format 17µm pixel pitch Resistive Pixels

MT6425DDA	MT3825DDA	MT10225DDA	MT10217BA
Dual-DI ROIC 640x512 format 25µm pixel pitch InSb, QWIP, MCT, T2SL	**Dual-DI ROIC** 384x288 format 25µm pixel pitch InSb, QWIP, MCT, T2SL	**Dual-DI ROIC** 1024x768 format 25µm pixel pitch InSb, QWIP, MCT, T2SL	**µBolometer ROIC** 1024x768 format 17µm pixel pitch Resistive Pixels

MT20415SA	MT40915SA	MT40910SA	MT6412BD
SF ROIC (Astronomy) 2048x2048 format 15µm pixel pitch Si, InGaAs, InSb, MCT	**SF ROIC (Astronomy)** 4096x4096 format 15µm pixel pitch Si, InGaAs, InSb, MCT	**SF ROIC (Astronomy)** 4096x4096 format 10µm pixel pitch Si, InGaAs, InSb, MCT	**µBolometer D-ROIC** 640x480 format 12µm pixel pitch Resistive Pixels

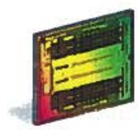
Test Electronics and Demo Cameras

MT-USB-CAM-6415

NanoCAM-6415

MT-USB-CAM-E6415

ROIC Driver and Digitizer ASIC Products



MTAS1410X2 / MTAS1410X4 (ROIC Driver and Digitizer ASICs)

Product Properties	
DI	Direct Injection
CTIA	Capacitive Trans-Impedance Amplifier
SF	Source Follower
ROIC	Readout Integrated Circuit
D-ROIC	Digital ROIC
Si	Silicon
InSb	Indium Antimonide
InGaAs	Indium Gallium Arsenide
MCT	Mercury Cadmium Telluride
QWIP	Quantum Well Infrared Photodetector
Dual-DI	Dual-Polarity Direct Injection
T2SL	Type II Superlattice
ASIC	Application Specific Integrated Circuit

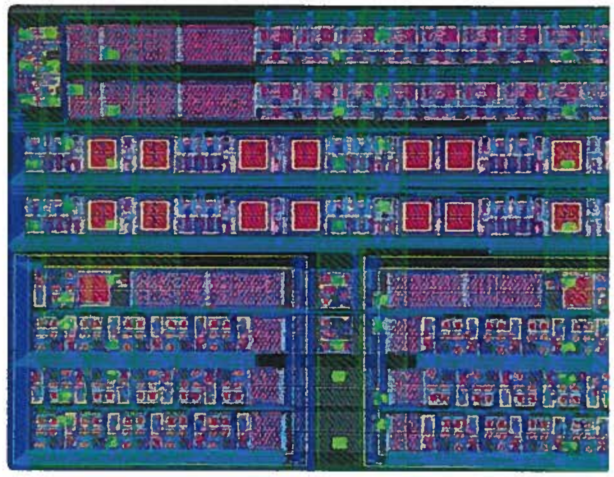
 Back to top

Custom infrared ROIC design

Custom ROIC design

Our ROIC design team is a group of highly skilled analog and digital designers. They design ROICs for InGaAs, QWIP, MCT, Bolometer, hybrid visible sensors or new emerging technologies. They create complex, high performance analog and digital full-custom CMOS integrated circuits. These offer major advantages to customers who seek customized solutions in applications where state-of-the-art designs are needed.

You can find examples of our designs in industrial automation, aerospace and aviation systems, automotive applications, (bio)-medical instrumentation, telecommunication, fiber optic sensing, and consumer products.



Full-custom designs generally require low noise, low dark current, or low power operation combined with high speed. Camera applications seek optimizations for short or long exposure times; complex windowing capability; specific pixel layouts. All these designs focus on the best possible performance level for a specific application, while keeping interfaces simple and recurring production costs low.

What do we offer?

Xenics has experience in a wide range of technologies and system applications but particularly in the field of infrared vision sensors. Our experience includes designs for high-performance, one-dimensional and two-dimensional, cooled as well as uncooled sensors for wavelengths ranging from NIR over SWIR, MWIR to LWIR.

Can't find what you're looking for?

Contact your regional support or sales team for help and detailed information.

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RELATED PRODUCTS

Xlin detector series

The Xlin detector series supports a unique combination of features for high-speed imaging applications in machine vision and spectroscopy.

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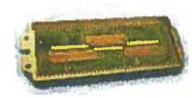

Xlin-1.7-3000

The high resolution Xlin-1.7-3000 InGaAs detector is specifically designed for earth observation.

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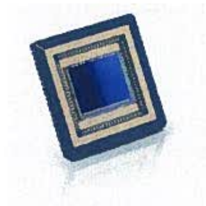

XFPA-1.7-640-LN2

The XFPA-1.7-640-LN2 excels in performance for any R&D spectroscopy or semiconductor failure analysis task.

LEARN MORE »

DOCUMENTS

PRESS RELEASES	**Xenics InGaAs SWIR detector is part of the Proba-V space mission**	Three Xlin-1.7-3000 linear arrays are launched into space aboard the ESA's Proba-V satellite (2013)
WHITEPAPERS	**First results of the Xlin-1.7-3000 on board of the Proba-V satellite**	The design, the qualification and the results of the Xlin-1.7-3000 on board of Proba-V satellite

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18/02/2015

PRODUCT NEWS

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09/02/2015

Professional service, knowledge and advice!

Secure in Air appreciates the professional service, knowledge and advice of Xenics in implementing the Gobi camera in our project GeoCampro. Our client was more than satisfied with the results, looking for (thermal) defects in the railways.

Robert de Nes, Secure in Air

Xenics nv
Ambachtenlaan 44
BE-3001 Leuven
Belgium

Contact us

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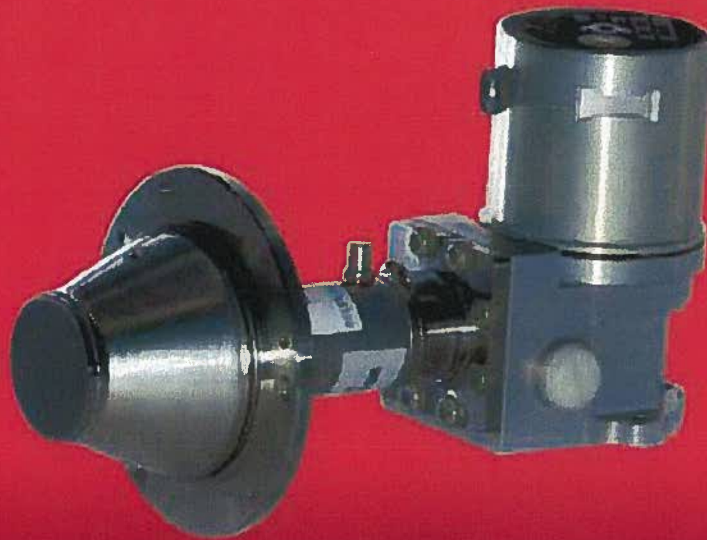


Optronics Systems

MERLIN
LONG WAVE INFRARED DETECTOR

Selex ES designs, develops and manufactures Infrared (IR) detectors at its dedicated facility in Southampton, UK. With a reputation for providing customers with the best in high performance and cost-effective technology for IR camera systems, Selex ES offers a unique level of expertise.

The Merlin Long Wave Infrared (LWIR) detector is a 1024 x 768 Mercury Cadmium Telluride (MCT) Integrated Detector Cooler Assembly (IDCA). The Merlin LWIR detector is designed for very high performance imaging in the 8 - 10μm waveband.

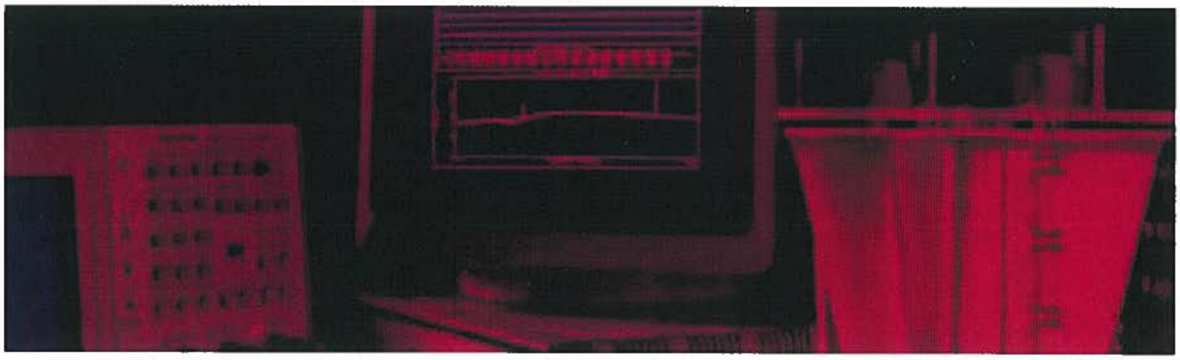
Using the Selex ES MCT process, the Merlin LWIR detector provides the highest environmental integrity along with the superior performance of focal plane detectors.

MAIN FEATURES

- Snapshot or interlaced operation
- Simple to use
- Long Wave (LW) 8 – 10μm
- Interlaced mode doubles charge capacity in each pixel for improved NETD
- High electro-optic performance with low crosstalk, automatic anti-blooming at the pixel level and excellent sensitivity
- Windowing gives enhanced frame rates over selected areas of the array
- Small element pitch enables miniaturisation of the Dewar assembly and optics
- Higher operating temperature than QWIPs
  - Longer cooler life
  - Less in-service support
  - Lower through-life cost
- Extremely short stare times for much less motion blur than QWIPs

KEY BENEFITS

- Low cost
- Compact
- Ultra high resolution
- High sensitivity



TECHNICAL SPECIFICATIONS

Format	
Array	1024 x 768 pixels
Pixel Pitch	16µm
Active Area	16.38 x 12.29mm

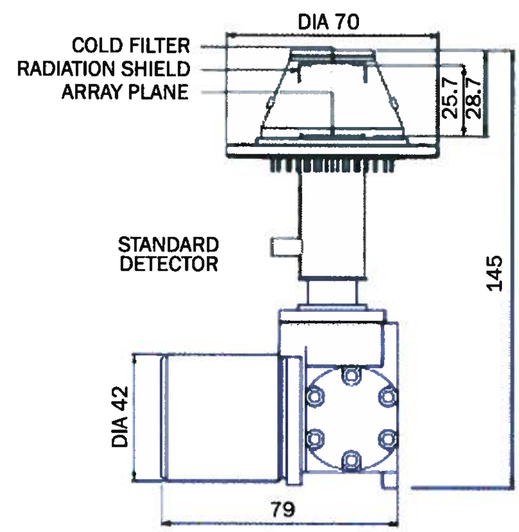
Typical Performance	
NETD (median)	32mK (23mK interlaced mode)
Pixel Operability	>99%

Interface Parameters	
Modes	Snapshot or interlaced
Configuration Control	Single serial interface
Output Voltage Range	2.5V
Charge Capacity	7 x 10^6 electrons (14 x 10^6 interlaced mode)
Number of Outputs	8
Pixel Rate	Up to 10MHz per output
Intrinsic MUX noise	50MV rms
Array Operating Temperature	Up to 90K
Nominal Operating Voltage	6V
Minimum Pins for Operation	20
Number of Input Clocks	1
Window Material	Germanium
Window Thickness	1.73mm
Cold Filter Material	Silicon
Cold Filter Thickness	0.4mm

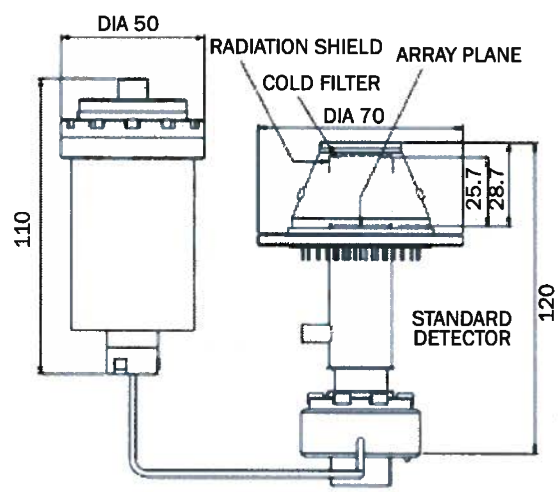
IDCA	
Weight	<750g
Power Consumption	<10W steady state
Cooling Engine	Rotary Stirling engine
Operating Temperature Range	-40°C to +70°C

LINEAR ENGINE VARIANT	
Weight	950g
Power Consumption	<15W steady state
Cooling Engine	Linear Stirling engine
Operating Temperature Range	-40°C to +70°C

IDCA



LINEAR ENGINE VARIANT

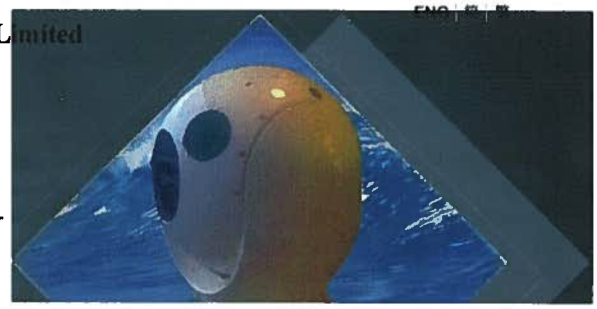


All dimensions in millimetres

For more information please email **infomarketing@selex-es.com**
Selex ES Ltd - A Finmeccanica Company
Millbrook Industrial Estate, Southampton, Hampshire, SO15 0LG, United Kingdom, Tel: +44 (0) 23 8070 2300, Fax: +44 (0) 23 8031 6777

Yiwu TianYing Optical Instrument Co., Limited

TianYing is the most innovative made of infrared thermal imaging camera, gyro stability thermal camera system, thermal weapon sight, laser rangefinder binoculars, and laser rangefinder module.



Product Catalog > Gyro Stability Thermal Camera Systems > Maritime Thermal Imaging Camera systems

4 Axis Platform 30km 640x512 Maritime Cooled Thermal Imaging Camera System

Model No. :	EOST-3000M
Brand Name :	TianYing
Country of Origin :	China
Unit Price :	-
Minimum Order :	2 set

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Product Description

The maritime cooled thermal imaging camera system survives in the harshest sea eavironment, auto tracking boat 30km, recognition suspect human activities up to 10km, mainly used for search and stable auto tracking task.

The system is composed by three parts: Pointer, Electronics Control Unit and Hand Control Unit. Pointer is including 640x512 30-600mm focus cooled infrared thermal imaging camera, visible light TV camera, high frequency laser rangefinder, 4 axis gyroscope stabilization turret and auto tracker. Hand Control Unit is including control key and operating lever, option display unit is included.

The maritime thermal camera system can be connected to a radar system, when the radar detects an object, the camera will automatically turn in the right direction and give you a visual image, so that you can instantly see what the blip on the radar screen really means, including fast moving objects.

EOST-3000M maitime thermal imaging camera system offer precise information and clear view, which is why TianYing Optical seeks to offer the most reliable surveillance solution. It is a fully stabilised, compactly designed surveillance system which bundles various state-of-the-art sensors. Thus, offering the user a large variety of functions comprised in only one device. EOST-3000M is available as a stand-alone unit or can be fully integrated into CMS and bridge systems.

Also it can be installed on vehicles or fixed mast for defense and security tasks.

EOST3000M 4-axis gyro stability platform 30km maritime cooled thermal camera system typical missions:
1) Maritime Patrol.
All weather surveillance, day/night long stand-off range detection, identification and tracking of naval targets.

2) Search And Rescue
All weather, day/night detection of naval units in distress and/or men at sea.

3) Coast Guard/Police Operations .
All weather, day/night detection and identification of illegal activities (immigration, smuggling, poaching, etc...).

4) Sentinel duties.
All weather, day/night support to independently perform surveillance, reconnaissance, target detection and track task when radar fails to work normally.

EOTS3000M 4-axis gyro stability platform 30km maritime cooled thermal camera system Main Features:
1) Stable 360 ° continuous turn gimble platfom with compact size and light weight.

2) High precision 4-axis gyroscope stabilization, the stabilisation accuracy: typical 20μradian .

3) High-performance 640x512 cooled thermal camera with powerful 20x optical zoom capability.

4) High-resolution, fully automatic visible light CCD camera with continuous 24x optical zoom.

5) Laser range finder with 1Hz, 2Hz, 5Hz, 20Hz continuous measureing frequency option.

6) Stable target tracking and Multi-model auto tracker.

7) Radar tracking and output target coordinate option.

8) Auto tracking boat beyond 30km, recognize suspect human activities up to 10km .

9) Capable of stand alone or integrated operations, independently perform surveillance, reconnaissance and target detection task when the radar fails to work normally.

10) Enables target detection in rough seas, supports all-weather, day or night missions, meets miliarys standard Mil-Std GJB 150 :Humidity, sand/dust, ice/freezing rain, shock, vibration,working low temperature (-40° C) and high temperature (+55 ° C).

EOST-3000M 4 axis grro stability 30km maritime thermal camera system Specification:

Model	EOST-3000M	EOST-2000M	EOST-100M
System type	4 axis stabilization	4 axis stabilization	2 axis stabilization
Azimuth range	360° continuous	360° continuous	360° continuous
Elevation range	-20° to +120°	-20° to +120°	-20° to +85°
Stabilization accuracy(RMS)	typical 20μrad	typical 10μrad	≤ 100μrad
IR thermal imager	cooled 640x512	cooled 640x512	uncooled 640x512
IR thermal imager FOV	18.3° to 0.9°	27.5° to 1.8°	6.2° x 5°
Detect human(94.5% success probability)	10km	5km	1500m
Recognize human(NATO 4347 STANAG)	6500m	3400m	1000m
Auto tracking helicopter/boat	≥30km	≥20km	≥5km
TV	Yes	Yes	Yes
Laser rangefinder	Yes	No	Option 2Hz continuous
Operating temperature	-40°C to 55°C	-40°C to 55°C	-40°C to 55°C
Environmental Standard	MIL-STD-GJB150	MIL-STD-GJB150	MIL-STD-GJB150
Weight	≤50kg	≤30kg	≤25kg

Note:
* According to NATO STANAG 4347, Detection need 1 lp/target that is 50% probability for 2°C temperature difference between target and background, Recognition need 3 lp/target, identification need 6 lp/target. Our detection human is use for 2 lp/target that is 94.5% success probability.

**Technical informantion is subject to change without notice.

EOST-3000M 4 axis gyro stability platform 30km maritime cooled thermal imaging camera system Included accessories In Standard Package:

Stabilized Three Sensor Gimbal System, Control Electronics Unit (CEU), Ergonomic Hand Control Unit (HCU), Cable Kit, Reusable shipping/storage case, Operator's Manual Kit.

Product Image

4 Axis Platform 30km 640x512 Maritime Cooled Thermal Camera System

Related Products

2 Axis Platform 5km 640x512 Maritime Thermal Imaging Camera System

4 Axis Platform 20km 640x512 Maritime Cooled Thermal Imaging Camera System

Company Address: Room 301, 1 unit, 18Building, Houcheng Yi Qu, Jiangdong Street Yiwu City,Zhejiang China. Post Code: 322000.

Telephone.:0086-579-85389306; Fax:0086-579-85380520; Mobile: 0086-13575936100(Jeny--English); 13515798545(Chinese).

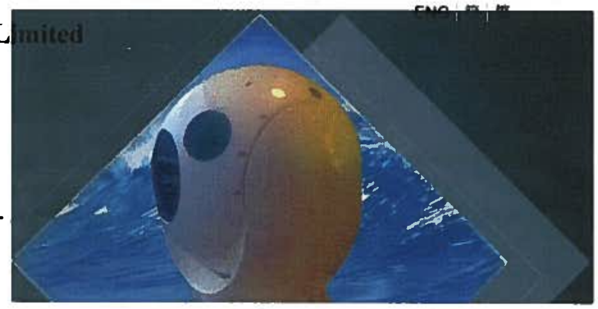
Email: info@nightvisioncn.com, hawksoptics@hotmail.com, hawksoptics@gmail.com.

MSN Chat: hawksoptics@hotmail.com, Skype chat: hawksoptics, QQ Chat: 573692657.

web: http://www.nightvisioncn.com, http://m.nightvisioncn.com.

Yiwu TianYing Optical Instrument Co., Limited

TianYing is the most innovative made of infrared thermal imaging camera, gyro stability thermal camera system, thermal weapon sight, laser rangefinder binoculars, and laser rangefinder module.



2 Axis Platform 640x512 75mm Lens UAV Thermal Imaging Camera System

Model No. :	EOST-210
Brand Name :	TianYing
Country of Origin :	China
Unit Price :	-
Minimum Order :	2 set

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Product Description

EOST-210 UAV Helicopter Thermal Imaging Camera System is a compact, lightweight, 0.04mrad stable accuracy, dual-sensor auto tracking system, designed for pursuit/patrol and surveillance missions. This model is based on the 8 inch gimbal design, configured for specific law enforcement missions.

It uses, both during night and day, a thermal imager operating in the long wavelength spectrum (8÷12μ), based on the 640x512 uncooled Focal Plane Array (FPA) detectors with 60mm or 75mm lens optics.

For day operations, including low light conditions, EOST-210 utilize a 36x zoom TV colour camera for target search. This colour high magnification, long range TV camera spotter is available for target identification,even at long distance.

EOST210 device is a high-performance sensor turret system of the lightest weight and most compact size in world, also it is the world's number one selling law enforcement multi-sensor turret system.

EOST-210 UAV thermal camera surveillance and tracking system Typical Missions:

1) Maritime Patrol.

All weather surveillance, day/night long stand-off range detection, identification and tracking of naval targets.

2) Search And Rescue.

All weather, day/night detection of naval units in distress and/or men at sea.

3) Coast Guard/Police Operations.

All weather, day/night detection and identification of illegal activities (immigration, smuggling, poaching, etc...).

4) Land Operations.

All weather, day/night support to the operation of multirole armed helicopters employed for patrol, escort or protection of ground troops.

EOST-210 UAV thermal imaging camera auto tracking system Applications:

1. Counter Drug.
2. Homeland Security.
3. Patrol.
4. Surveillance.
5. Reconnaissance.
6. Search And Rescue.

EOST-210 UAV thermal imaging camera system Main Features:

1. Compact 8 inch gimbal

2. Light weight only 10kg with dual sensors.
3. High definition color CCD camera with 36x continuous focus optical.
4. Large format 640x512 IR with 75mm lens optics or 60mm lens optics.
5. High precision 2-axis gyroscope stabilization, the stabilisation accuracy: typical 40μradian (RMS).
6. Real-time offer high quality infrared thermal image and high definition visible light image at same time
7. Multi-model auto tracker
8. Human bionics controller.
9. Simplified common interface standard
10. Supports all-weather, day or night missions, meets miliarys standard Mil-Std GJB 150 :Humidity, sand/dust, ice/freezing rain, shock, vibration,working low temperature (-40° C) and high temperature (+55 ° C).

EOST-210 UAV/helicopter thermal camera system Sepcification:

Model	**EOST-210**
System type	2 axis gryo stabilization
Azimuth range	360° continuous
Elevation range	-120° to +20°
Stabilization accuracy(RMS)	typical 40μrad
IR thermal imager.	uncooled 640x512
NETD	Typical 40mk F1.0 @ 30° C
IR lens diameter	75mm F1.0
Field of View,°, horizontal * vertical	8.3° x 6.6°
IR stadia capability(human target)	≥1000m
IR stadia capability(vehicle target)	≥2000m
Mid range TV	Yes
Laser rangefinder.	No
Auto tracking	Yes
Environmental Standard	MIL-STD-GJB150
Gimbal diameter	8 inch
Weight	10kg
Standard Package	Stabilized Gimbal Assembly, Electronics Control Unit, simplified hand control unit, standard cable kit.

Note *- Technical information is subject to change without notice. ** -Depending on the region of sale

Product Image

2 Axis Platform 640x512 75mm Lens 40mK UAV Thermal Imaging Camera

Company Address: Room 301, 1 unit, 18Building, Houcheng Yi Qu, Jiangdong Street Yiwu City,Zhejiang China. Post Code: 322000.

Telephone.:0086-579-85389306; Fax:0086-579-85380520; Mobile: 0086-13575936100(Jeny--English); 13515798545(Chinese).

Email: info@nightvisioncn.com, hawksoptics@hotmail.com, hawksoptics@gmail.com.

MSN Chat: hawksoptics@hotmail.com, Skype chat: hawksoptics, QQ Chat: 573692657.

web: http://www.nightvisioncn.com, http://m.nightvisioncn.com.

765 Sycamore Drive Milpitas CA 95035
T 408 737 0992 F 408 736 8708 e2v-us.com

June 25, 2015

Office of Defense Trade Controls Policy
United States Department of State
Washington D.C

Re: ITAR Amendment—Category XII Comments

Dear Sirs:
We are commenting on proposed changes to USML Category XII, section c (7) regarding certain charge multiplication focal plane arrays and section c (8) regarding certain charge multiplication focal plane arrays in a permanent encapsulated sensor assembly.

It is our belief that while providing some restriction on the proliferation of charge multiplication focal plane arrays of US origin for military use, implementation of these changes as written would also hamper US based research in fields that are clearly non-military.

We propose that the following changes be made to this document:

- Clarify that the number of elements in an FPA refers only to those elements with radiant sensitivity exceeding the limit.
- Modify restrictions on the number of elements in a controlled FPA from >1600 to >2048.
- Exclude charge multiplication focal plane arrays that do not contain an internal electronic shutter.
- Exclude charge multiplication focal plane arrays with a maximum frame rate of 9 frames per second or less.

Electron multiplication charge-coupled devices (EMCCDs) have transformed many research areas but perhaps none more than life science research. In 2014 the Nobel Prize in Chemistry was awarded for super resolution fluorescent microscopy, an imaging technique enabled by EMCCDs. One of the prize recipients, Eric Betzig, did his work in Virginia, USA.

If the proposed changes to the USML are put in place, researchers in the US will not have access to a next-generation of high resolution EMCCDs. The restrictions on access to controlled technology by foreign nationals will effectively cut off their use in universities and research institutions. Foreign researchers outside the US will not suffer from these restrictions, putting them at an advantage. In order to level the playing field, the number of elements in a controlled FPA should be raised to at least 2049 or more.

The proposed rule does not distinguish between FPAs that contain an internal electronic shutter and those that do not. Full frame FPAs require an external shutter to block out light during readout while FPAs with an internal electronic shutter may be read out while exposing a new image. This reduces their *average* sensitivity by half and gives them limited usage in unpredictable dynamic imaging conditions. They are however, still quite useful in a controlled laboratory environment. FPAs without internal electronic shutters should be excluded.

Most e2v EMCCDs are manufactured with a metal mask covering some of the pixels in the focal plane array, rendering them insensitive to light. For example, a metal mask is used to cover the outer rows and columns of an image sensor in order to provide a dark reference. At e2v the metal mask is applied as part of the EMCCD fabrication process and cannot be removed without rendering the image sensor inoperable. The amendment e2v

wording should be changed to make it clear that the number of elements in an FPA refers only to those elements with radiant sensitivity.

e2v is a manufacturer of electron multiplication charge-coupled devices (EMCCDs). All e2v EMCCDs are manufactured in the United Kingdom and are sold through e2v's global sales offices. e2v EMCCDs are sold into the US and Canada and into various countries in Europe and Asia.

Over 95% of e2v EMCCDs sold in the US are supplied to OEM camera manufacturers who in turn manufacture cameras for end users in government institutions, universities and in industry. The largest end use market for EMCCD cameras is life sciences but they are also used in physical sciences such as spectroscopy and plasma diagnostics.

With enactment of this amendment, sales of ITAR controlled e2v EMCCDs into the US would be greatly curtailed. The reason for this is twofold: 1) it would be very difficult for e2v to honor its warranty since warranty return of EMCCDs to the UK would require an export license, putting an undue burden on e2v's US based customers and 2) US based OEM manufacturers of ITAR controlled EMCCD cameras would find their market outside of the US or into US institution employing foreign nationals greatly reduced by the time and difficulty inherent in obtaining an export license.

Enactment of these amendments would have no effect on the export of EMCCDs or EMCCD cameras out of the UK. Within the UK EMCCDs are considered dual use. EMCCDs may be exported from the UK to other EU member states without an export license being required. For exports to the following 7 countries – USA, Canada, Australia, New Zealand, Norway, Japan and Switzerland (including Lichtenstein) - there is an EU open export license available (Union General Export Authorisation No EU001). Exports to other countries require an individual export license from the UK government.

Sincerely,

Alice Reinheimer
Senior Applications Engineer
Space Imaging

Beth Mitchell
Export Control Manager/TCO
Empowered Official

July 6, 2015

Via Email – DDTCPublicComments@state.gov

Mr. C. Edward Peartree
Director, Office of Defense Trade Control Policy
Directorate of Defense Trade Controls
U.S. Department of State
2401 E. St, NW, 12th Floor, SA-1
Washington, DC 25022

Subject: **Comments on Proposed Revisions to USML Category XII**
80 *Fed. Reg*. 25,821 (May 5, 2015); RIN 01400-AD32

Dear Mr. Peartree:

Elbit Systems of America, LLC ("ESA") welcomes the opportunity to provide comments on the proposed revisions to USML Category XII (Fire control, range finder, optical and guidance and control equipment) of the International Traffic in Arms Regulations (ITAR).

Our comments, detailed below, propose several changes and fall into two general categories:

- Requests for clarification or modification of certain terms and important explanatory notes that are critical for defining the precise scope of Category XII(c); and

- Modifications to certain technical control parameters to ensure that Category XII(c) does not capture systems (or components thereof) that are in normal commercial use and available from foreign suppliers.

I. BACKGROUND

Our comments address how the proposed revisions to Category XII(c) would negatively affect U.S. industry in connection with the future development, sale and support of one specific type of infrared imaging system that currently is in widespread use on commercial transport aircraft and business jets – enhanced vision systems ("EVS"). These systems primarily use cooled infrared imaging systems to provide improved pilot visibility. The EVS system allows flight operations and identification of runway lights/ground features in darkness, smoke, haze, rain, fog and other low visibility conditions. EVS systems are widely used on civil aircraft (*e.g.*, commercial transport aircraft and business jets). EVS systems also are available on the commercial market from foreign suppliers, including CMC Electronics (Canada) and Thales (France).

Based on our review, it does not appear that the U.S. Government agencies involved in this process have sufficiently considered the extent to which the proposed revisions to Category XII(c) will negatively impact U.S. companies that manufacture, sell and support commercial EVS systems. If implemented as drafted, the requirements and restrictions in proposed Category XII(c) that will be applicable to EVS systems (and key components thereof) will curtail the use of such systems by imposing unreasonable burdens on sale and support activities, and will discourage future development and implementation of advanced infrared imaging technology into EVS systems. Ultimately, these overly broad restrictions could affect aviation safety and could cause potential owners and operators to purchase foreign-origin systems to the detriment of U.S. industry.

Due to the uncertainty of jurisdiction determinations, U.S. companies in the infrared imaging sector have obtained Commodity Jurisdiction determinations covering current versions of their systems. DDTC has clearly and consistently reaffirmed that previous CJs will remain valid notwithstanding the final revisions USML Categories resulting from the Export Control Reform process. *See, e.g.,* 78 *Fed. Reg.* 22740, 22750 (Apr. 16, 2013).

A primary concern, however, is how the proposed changes to Category XII(c) will affect the next-generation of commercial EVS systems. Next-generation EVS systems will almost certainly incorporate higher-performance IRFPAs and other components – the specifications and performance capabilities of which may be captured by this proposed revision of Category XII(c). There is no guarantee that past trends of obtaining CJ determinations that such systems are subject to the EAR will continue under the revised Category XII, and lack of clarity in the important explanatory notes and definitions (discussed below) may lead to uncertainty in the controls over future EVS systems, or – at worst – ITAR control over these purely commercial systems. Should this occur, U.S. industry will be placed at an extreme competitive disadvantage vis-a-vis foreign suppliers of EVS systems.

II. COMMENTS ON DEFINITIONS & EXPLANATORY NOTES

A. <u>Note 2 to Paragraph (c)</u> – Two proposed changes

1. Clarify the specific requirements for paragraph (c) articles to become subject to the EAR after integration into EAR items – including further elaboration on what is considered "inoperable"

Note 2 to paragraph (c) defines a release from ITAR controls for certain articles identified in paragraph (c) when such articles are incorporated into EAR items. Specifically:

> The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), and (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable.

Assuming that an eligible paragraph (c) "article" is integrated into and included as an integral part of an "item" subject to the EAR, then – as Note 2 currently is drafted – the paragraph (c) article will be subject to the EAR if it (*i.e.*, the paragraph (c) "article") cannot be removed from the EAR item without:

1. Destruction or damage to the "article" (*i.e.*, the paragraph (c) article); <u>*or*</u>

2. "render the item inoperable."

The first situation described above appears fairly straightforward. A paragraph (c) article meets the requirement of Note 2 and is subject to the EAR if it is integrated into an EAR item and cannot be removed from that EAR item without damage or destruction of the paragraph (c) article.

The second situation under which the paragraph (c) article becomes subject to the EAR requires clarification. In this situation, "inoperable" describes the "item," which clearly refers to the EAR item into which the paragraph (c) article is integrated. This is consistent with the presumably intentional use of the terms "item" and "article" in the beginning of Note 2 and well-established ITAR and EAR terminology (*i.e.*, the EAR controls "items;" the ITAR controls defense articles). The proposed language, however, does not provide clear guidance regarding the circumstances under which an EAR item will retain its EAR jurisdiction if it incorporates an article that is enumerated in paragraph (c).

<u>Proposed Change(s)</u>:

- Clarify that Note 2 to paragraph (c) does *not* in either situation described above require destruction or damage to the EAR item upon removal of the paragraph (c) article. Rather, all that is required to satisfy the requirements of Note 2 is that the removal of the paragraph (c) article must result in a situation where the EAR item is rendered "inoperable." The revised Note 2 also should specifically state that "inoperable" does not mean "destroyed or damaged" but simply means that the EAR item is incapable of being operated for its intended purpose until such time as the paragraph (c) article – or a one-for-one replacement thereof– is placed back into the EAR item.

- Alternatively, if the intent of Note 2 was to require that removal of the paragraph (c) article would result *in the paragraph (c) article* being rendered "inoperable," then the closing language of Note 2 should be revised to state:

  > …and cannot be removed without destruction or damage to the article or render**ing** the ~~item~~ **article** inoperable.

  If this was the intent, the revised Note 2 should clarify that "inoperable" in this case has a meaning similar to that described above (*i.e.*, the paragraph (c) article is incapable of being operated for its intended purpose once it has been removed from the EAR item). Further, the note should clarify that no damage or destruction to the paragraph (c) article is required to render the paragraph (c) article "inoperable" for purposes of applying Note 2 to paragraph (c). Rather, the article can be rendered "inoperable" by design limitations, such as unique interfaces or operating software that would not allow the paragraph (c) article to operate as intended in any higher-level system other than the type of EAR item for which the article was designed or manufactured.

Finally, the same clarifying changes described above should be made to the Note to paragraph (e). The Note to paragraph (e) is essentially identical to Note 2 to paragraph (c) except that the Note to paragraph (e) applies to parts, components, accessories, attachments and associated equipment identified in proposed paragraph (e) rather than articles in paragraph (c).

2. Note 2 to paragraph (c) should include IDCAs described in paragraph (c)(9)(i) within its scope

Only certain items listed in the first sentence of Note 2 to paragraph (c) are eligible to become subject to the EAR if they satisfy the requirements of the Note. The articles that are eligible for such treatment include most of the major building blocks for infrared imaging systems – IRFPAs described in paragraph (c)(2), several types of permanently encapsulated sensor assemblies described in paragraphs (c)(3) to (c)(5) and certain infrared camera cores described in paragraph (c)(12).

The list of articles eligible for Note 2, however, does *not* include the following articles described in paragraph (c)(9)(i):

> Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours

The omission of paragraph (c)(9)(i) from Note 2 to paragraph (c) would defeat the entire purpose of the Note – at least as it applies to cooled infrared imaging systems. The IDCA integrates the IRFPA and the required cooling system into a single, combined unit. This increases reliability and thermodynamic efficiency, and allows the system to be cooled by a smaller cryocooler with lower power consumption. Virtually all cooled infrared imaging systems incorporate an IDCA.

Although the use of cooled infrared imaging systems traditionally has been more widespread in military applications, there are now well-established commercial applications for cooled systems – and it is expected that the commercial market for cooled systems will continue to expand. One such application is EVS systems. Others include scientific research and industrial test and measurement applications (*e.g.*, semiconductor inspection equipment), described in Section III(A) below. The majority of EVS systems used on civilian aircraft are cooled systems that incorporate IDCAs. Moreover, as described below, we understand that the cryocoolers incorporated into IDCAs for systems used in commercial applications have performance capabilities that greatly exceed those currently specified in paragraph (c)(9)(i).

The purpose of Note 2 to paragraph (c) is to suspend the ITAR principle often referred to as the "see through" rule and enable certain types of infrared imaging systems to be exported as EAR items even if such items incorporate individual articles that are identified in paragraph (c) – provided that the terms of paragraph (c) are satisfied. By virtue of Note 2, an EAR item can incorporate a paragraph (c)(2) IRFPA, a permanent encapsulated sensor assembly in paragraphs (c)(3) to (c)(6) or certain infrared imaging cores in (c)(12) and still be exported as an EAR item.

Omitting IDCAs in paragraph (c)(9)(i) from Note 2, however, destroys any benefit of Note 2 for U.S. companies that manufacture, sell and support commercial cooled infrared imaging systems. All cooled infrared imaging systems incorporate an IDCA. Thus, as Note 2 is currently drafted, it would appear that any cooled infrared imaging system that incorporates an IDCA with what we understand to be a standard commercial cryocooler will not be eligible for Note 2 and will continue to be subject to ITAR controls – even if that system was clearly developed for, marketed, sold and used solely for commercial applications.

This outcome does not make sense for policy reasons. One important purpose of Note 2 appears to be that it allows U.S. companies to compete with foreign suppliers of cooled systems for sales in commercial applications, while retaining ITAR controls over certain individual components and technologies incorporated in those systems. Such treatment may be warranted when certain very high-performance IRFPAs or camera cores with special capabilities unique to the military are incorporated into an EAR item. However, we understand that most cryocoolers currently used in IDCAs available on the commercial market from foreign suppliers satisfy the very low performance and reliability requirements specified in paragraph (c)(9)(i). It is not clear why Note 2 would allow for a commercial infrared imaging system to remain subject to the EAR if it incorporates a high-performance IRFPA that is classified in paragraph (c)(2) or an equally capable permanent encapsulated sensor assembly in paragraphs (c)(3) to (c)(5), but that same system incorporating an IDCA with a much less capable IRFPA and a standard, commercially available cryocooler would not be eligible for Note 2.

The omission of paragraph (c)(9) from Note 2 also does not make sense when the overall structure and organization of paragraph (c) is considered. Paragraph (c) starts with bare IRFPAs, then identifies permanent encapsulated sensor assemblies, then IDCAs, then camera cores and ultimately complete infrared imaging systems. As explained in the Federal Register notice, once a lower level article is incorporated into a higher order system, the higher order system will not be subject to the ITAR unless it is specifically enumerated. The regulatory language that achieves this objective is Note 2 to paragraph (c). At each level, most paragraphs are eligible for Note 2, with certain, specified exceptions (*e.g.*, multispectral IRFPAs, sensor assemblies and camera cores). However, *none* of the IDCAs in paragraph (c)(9) are eligible for Note 2. This is even more confusing when one considers paragraph (c)(12)(iv), which identifies complete infrared imaging camera cores that include an IDCA described in paragraph (c)(9). The camera core in paragraph (c)(12)(iv) is eligible for Note 2. However, the same IDCA in that camera core would not appear to be eligible for Note 2 when included in a different higher order system.

<u>Proposed Change(s)</u>: Revise the first sentence of Note 2 to paragraph (c) to include articles identified in paragraph (c)(9)(i) as follows:

> The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), **(c)(9)(i),** ~~and~~ (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR …

B. <u>Note 1 to Paragraph (c)</u> – Clarify what constitutes a "permanent encapsulated sensor assembly"

Please provide further clarification as to the meaning of Note 1 to paragraph (c).

In addition, we request that the reviewing agencies consider the effect that the proposed definition of "permanent encapsulated sensor assembly" will have on the ability of U.S. companies to provide repair and maintenance services for infrared imaging systems used in exclusively commercial applications. For owners and operators of EVS systems, total cost of ownership is extremely important. A definition of "permanent encapsulated sensor assembly" that requires destruction or damage to the IRFPA or the sensor assembly upon access or removal effectively prevents any repairs to the sensor assembly. The cost to replace a faulty sensor assembly with an entirely new sensor assembly can be very expensive. For this reason, the sensor assembly – as well as other individual components and LRUs – must be repairable in some manner to keep system costs contained.

Instead of a standard that requires damage or destruction to the IRFPA, the reviewing agencies should consider a standard that recognizes that repairing a sensor assembly requires a high degree of knowledge, specialized tooling and fixtures, and that such activities are normally performed by the manufacturer. Moreover, the definition should reflect the fact that these types of IRFPAs and sensor assemblies are highly engineered products that are packaged and integrated into higher level systems through complex manufacturing processes. They cannot be simply "unplugged" and easily diverted to another application.

<u>Proposed Change(s)</u>: Consider modifying Note 1 to paragraph (c) to read as follows:

> A permanent encapsulated sensor assembly (*e.g.,* sealed enclosure, vacuum package) **is one that is not designed to be easily disassembled and requires specialized tooling, fixtures and engineering knowledge to disassemble without causing damage or destruction to the sensor assembly, the IRFPA or its other components.**

C. Include the definition of "multispectral" from the explanatory language of the *Federal Register* Notice in the regulations

The term "multispectral" is used as a control parameter in revised paragraphs (c)(2), (c)(6), (c)(12)(x), (c)(16)(v) and (e)(4)(iv). This term, however, is not defined in the text of the proposed paragraph (c).

Proposed Change(s): Include the definition of "multispectral" within the text of the revised Category XII to clarify the scope of the paragraphs in Category XII that rely on this term as a control parameter.

III. COMMENTS ON SPECIFIC CONTROL PARAMETERS IN CATEGORY XII(C)

One core principle of the Export Control Reform initiative is that items in normal commercial use should not be identified on the USML unless such items provide the United States with a critical military or intelligence advantage. The *Federal Notice* detailing the proposed revisions to Category XII specifically claims the following with respect to the technical control parameters in revised Category XII(c): "These control parameters are set at a level that the Department has determined excludes most commercial products."

It appears, however, that several of the control parameters in the proposed revisions to paragraph (c) will capture articles that we believe are in normal commercial use and are available from foreign suppliers. Unintended controls over such articles can be avoided, however, with changes to certain explanatory notes and definitions (*see* Section II), as well as with certain specific adjustments to the proposed control parameters for several paragraphs in proposed paragraph (c). These modifications will ensure that the revised paragraph (c) does not impose controls over IRFPAs, sensor assemblies and related items that are manufactured and sold by foreign companies for use in commercial applications. We have provided specific comments below, along with examples that "demonstrate actual commercial use, not just potential or theoretical use, with supporting documents, as well as foreign availability of such items." *See* 80 *Fed. Reg.* 25,821 (May 5, 2015).

A. Paragraph (c)(2) – Limit overly broad scope by including a "specially designed" limitation

Revised paragraph (c)(2) would control IRFPAs of various types that are not integrated into a permanent encapsulated sensor assembly (*i.e.*, bare IRFPAs).

The proposed language would control virtually all bare IRFPAs regardless of the nature of the application for which they were developed or in which they are used. All IRFPAs that meet these minimal requirements would be subject to control under paragraph (c)(2), even if they were originally designed for use in "dual use" or entirely commercial applications and have been used exclusively in such applications. Numerous commercial and civil applications, including EVS systems, utilize IRFPAs that would be captured by the extremely broad language of proposed paragraph (c)(2).

U.S. industry is not the predominant designer or manufacturer of infrared imaging technology worldwide. Although there is design and production activity in the United States, a substantial amount of research, development and production of IRFPAs, infrared imaging systems and related items currently occurs outside of the United States, namely in:

- Israel (Semiconductor Devices Ltd.)

- France (ULIS, SOFRADIR)
- Japan (Hamamatsu Photonics K.K.)
- United Kingdom and Italy (Selex ES)
- Germany (AIM Infrarot Module GmbH, Optris)
- Belgium (Xenics NV)

We understand that these foreign companies have conducted extensive research and development and have worked to advance the use of high-end infrared imaging systems in a wide variety of commercial and civil applications. For example, we understand that cooled IRFPAs manufactured by Semiconductor Devices Ltd. in Israel are sold worldwide for use in a wide variety of commercial applications, such as:

- Scientific research and development applications, such as geology and earth mapping, mineralogy studies, surface and emissivity studies, gaseous cloud studies and art inspection;

- Public health and safety applications, such as security systems, pollution monitoring, firefighting and forest fire monitoring;

- Industrial applications, such as predictive maintenance, leak detection in electrical utilities and manufacturing plants, non-destructive testing, process and quality control applications, mapping, high temperature thermography, semiconductor inspection, non-contact temperature measurements; and

- Navigation systems, such as EVS systems and automobile enhanced vision systems

In addition to SCD, we understand the following foreign companies also develop, manufacture and sell photon detector IRFPAs and detector modules for use in commercial infrared systems include:

- SOFRADIR (France), *see* http://www.sofradir.com/products/

- Selex ES (United Kingdom and Italy), *see* http://www.selex-es.com/product-portfolio/optronics-system/thermal-detectors

- Hammamatsu Photonics K.K. (Japan), *see* http://www.hamamatsu.com/us/en/product/category/3100/4007/4165/index.html

- Xenics NV (Belgium), *see* http://www.xenics.com/en/products/cameras?f[0]=field_cooled_term%3A632

Proposed Change(s): Use the established definition of "specially designed" in ITAR §120.41 to narrow the overly broad scope of paragraph (c)(2) as follows:

> Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) **specially designed for defense articles in this subchapter;** ~~and~~ having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm; and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor

Including a "specially designed" qualifier would be consistent with other USML Categories that have been revised as part of the Export Control Reform process. As frequently explained by DDTC and BIS officials, the purpose of the "specially designed" definition is to provide a consistent and objective method to identify items that, as a result of development, have properties peculiarly responsible for achieving or exceed relevant performance levels, characteristics or functions. Thus, limiting paragraph (c)(2) to IRFPAs that are "specially designed" for defense articles would provide a clear method for excluding from ITAR control IRFPAs that were designed exclusively for commercial applications or that have demonstrably been sold for and used in bona fide commercial applications, while maintaining ITAR controls over those IRFPAs that have some feature, performance capability or characteristic particular to military applications.

In addition, as noted above, the definition of the term "multispectral" should be included in or immediately after paragraph (c)(2), since this is the first use of the term in Category XII(c).

B. <u>Paragraph (c)(4)</u> – Increase control parameter for number of detector elements and/or include "specially designed" limitation

Revised paragraph (c)(4) would control:

> Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 256 detector elements.

The control parameter of "256 detector elements" requires further clarification. An IRFPA with 256 *total* detector elements would have a resolution of 16 x 16 or lower. Our engineers are not aware of any two-dimensional IRFPAs with such a small number of total detector elements. Certain one-dimensional IRFPAs may have total detector elements at this level. However, one-dimensional photon detector IRFPAs are specifically addressed in proposed paragraph (c)(3), which includes a control parameter of greater than 640 total detector elements. Thus, it appears that the intent of proposed paragraph (c)(4) may have been to control IRFPAs in a permanently encapsulated sensor assembly having greater than 256 detector elements *in any dimension* rather than IRFPAs simply having greater than 256 total detector elements.

Even if the intent was to control IRFPAs with greater than 256 detector elements "in any dimension," we believe that this parameter is still be far below the resolution of photon detector IRFPAs that are used in established commercial infrared imaging systems. For example, according to publicly available marketing information:

- Thales (France) manufactures an Enhanced Vision System for use on civilian transport and business jet aircraft with a 1024 x 768 resolution IRFPA, which equates to 787,000 total detector elements. *See* https://www.thalesgroup.com/sites/default/files/asset/document/thales_evs_sheet_canada.pdf.

- CMC Electronics (Canada) manufactures the CMA-2700 Enhanced Flight Vision Systems for use on civilian transport and business jet aircraft with a 640 x 512 pixel InSb IRFPA, which equates to 327,680 total detector elements. *See* http://www.cmcelectronics.ca/pdf/SureSight_4pager.pdf.

- DCG Systems, Inc. sells a semiconductor inspection system that includes a cooled infrared camera with a 1024 x 1025 pixel MCT IRFPA, which equates to 1,049,600 total detector elements. *See*, e.g., http://dcgsystems.com/products/electrical-fault-analysis/meridian-line/meridian-iv/ (This camera was determined to be subject to the EAR and classified in ECCN 6A002.b.4 via a December 2014 Commodity Jurisdiction.)

- Telops, Inc. (Canada) sells the TS-IR Thermal Scientific IR Camera, with a cooled InSb or MCT IRFPA of 640 x 512 pixels, which equates to 327,680 detector elements. *See* http://www.telops.com/en/infrared-cameras/ts-ir-thermal-scientific-ir-camera

Finally, as noted in Section III(A) above, two dimensional photon-detector IRPFAs (or detector modules incorporating such IRFPAs) with total detector elements greatly exceeding 256 are available from multiple suppliers worldwide – including SCD Ltd, SOFRADIR (France), Xenics (Belgium), Hammamatsu (Japan) and Selex (U.K. & Italy).

Proposed Change(s): To reflect the current performance capabilities of two-dimensional photon detector IRFPAs that are available from foreign suppliers and used in commercial applications, paragraph (c)(4) should be modified as follows:

> Two-dimensional photon detector IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, having greater than ~~256~~ **1024** detector elements **in any dimension**.

Alternatively, instead of adjusting the technical parameters, DDTC could achieve the same objective by incorporating a "specially designed" limitation, as follows, for the same reasons described in Section III(A) above:

> Two-dimensional photon detector IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, **specially designed for defense articles in this subchapter** and having greater than 256 detector elements **in any dimension**.

C. Paragraphs (c)(6), (c)(12)(vi) & (c)(12)(ix) – Increase the lower end of the wavelength range control parameter

The control parameters in paragraphs (c)(6) (for multispectral IRFPAs) and (c)(12)(vi) & (ix) (infrared imaging camera cores) are based on the article having a peak response within a range of wavelengths, as follows:

Paragraph	Peak Response Wavelength
(c)(6)	Any spectral band between 1,500 nm and 30,000 nm
(c)(12)(vi)	Any spectral band between 2,500 nm and 30,000 nm
(c)(12)(ix)	Any spectral band between 2,500 nm and 30,000 nm

EVS systems that are in normal commercial use on civil aircraft operate in the 400 nm – 5,000 nm spectral band because this is the spectral band that includes airport/runway approach lighting and enhanced LED lighting. An approach to the airport during marginal weather is the most critical phase of an aviation enhanced vision system. The pilot must be able to see the airport approach lights and then the airport environment to enable him/her to continue the approach to landing.

Proposed Change(s): To avoid capturing IRFPAs and camera cores that operate in a spectral range applicable to visible and enhanced LED lighting, we propose increasing the lower limit of the wavelength range control parameter for the paragraphs cited above as follows:

(c)(6) Multispectral IRFPAs in a permanent encapsulated sensor assembly, having a peak response in any spectral band within the wavelength range exceeding ~~1,500 nm~~ **6,000 nm** but not exceeding 30,000 nm.

(c)(12)(vi) A one-dimensional or two-dimensional photon detector IRFPA described in (c)(2) having a peak response within the wavelength range exceeding ~~2,500 nm~~ **6,000 nm** but not exceeding 30,000 nm and greater than 256 detector elements **in any one dimension**

(c)(12)(ix) A two-dimensional photon detector IRFPA described in (c)(4) having a peak response within the wavelength range exceeding ~~2,500 nm~~ **6,000 nm** but not exceeding 30,000 nm

D. Paragraphs (c)(9)(i) & (e)(7)(i) – Decrease the temperature threshold and increase the MTBF threshold for cryocoolers

Proposed paragraph (c)(9)(i) would control IDCAs that have "a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours."

Proposed paragraph (e)(7)(i) would control the individual cryocoolers that have the same performance and reliability specifications.

As noted above, most EVS systems used on civil aircraft incorporate cooled infrared imaging systems, which means that they must incorporate a cryocooler to maintain the IRFPA at a very low temperature. Based on our research, the proposed control parameters for cryocoolers focusing on temperature and reliability metrics are set at levels that are well below those of cryocoolers that are currently used in commercial applications and that are available from foreign suppliers.

- Temperature: Most cooled infrared detectors operate in the 60 K to 100 K range (*i.e.*, -213°C to -193°C), depending on the detector type and performance level. A cryocooler that is designed to operate at 77 K is very common because this temperature is relatively easily achievable with liquid nitrogen. These levels are well below the proposed control parameter of 218 K (-55°C).

- MTTF: An MTTF of only 3,000 hours is *far below* the current reliability levels of cryocoolers that are available from foreign suppliers. The product selection website of Thales (France), a major foreign manufacturer and supplier of cryocoolers, indicates that the *lowest* MTTF for any of the cryocoolers on the website is 24,000 hours – or *8 times* longer than the proposed MTTF threshold. *See* http://www.thales-cryogenics.com/product-category/coolers/.

In addition, it is not clear why the proposed control parameter for reliability is based on "mean-time-to-failure" ("MTTF") rather than "mean-time-between-failures" ("MTBF"). MTBF is the expected time between two successive failures of an item or a system. MTTF is the expected time to failure, which implies that the item or system is a consumable (*i.e.*, not repairable). Our experience has been that the commercial marketplace prefers MTBF as a metric because it indicates that the system is repairable, thus more cost effective. As noted above, cost of operation is extremely important. Customers and operators of EVS systems demand high reliability components. Customers have contractual MTBF requirements that exceed 10,000 hours – well above the proposed 3,000 hour MTTF threshold. If MTTF is retained as a control parameter, then the reviewing agencies should consider also including MTBF at a level equivalent to the final MTTF figure.

Proposed Change(s): Paragraphs (c)(9)(i) and (e)(7)(i) should be modified as follows:

(c)(9)(i) Cryocoolers having a cooling source temperature below ~~218 K~~ **77 K** and a ~~mean-time-to-failure (MTTF)~~ **mean-time-between-failure** (**MTBF**) in excess of ~~3000 hours~~ **10,000 hours**

(e)(7)(i) Cryocoolers having a cooling source temperature below ~~218 K~~ **77 K** and a ~~mean-time-to-failure (MTTF)~~ **mean-time-between-failure** (**MTBF**) in excess of ~~3000 hours~~ **10,000 hours**

* * *

If you have any questions concerning these comments, please do not hesitate to contact Karen Wyman, ESA's Trade Compliance Manager responsible for assembly of these comments, at 603.886.2206 or via email at karen.wyman@elbitsystems-us.com.

Sincerely,

Ben Gaffield
Corporate Technology Control Officer &
Director, Trade Compliance

cc: Regulatory Policy Division
Bureau of Industry and Security
U.S. Department of Commerce
14th Street & Pennsylvania Ave., NW
Washington, DC 20230
Ref: **RIN 0694-AF75**

From: efy
To: DDTCPublicComments
Subject: ITAR Amendment—Category XII.
Date: Monday, July 06, 2015 5:18:48 PM

To: US Department of State
Subject: Proposed changes to bring ICCD, EMCCD and InGaAs camera technologies under ITAR regulations

Dear Sir/Madam:

I am an astronomer at Southwest Research Institute in Boulder, CO. My colleagues and I have funded NASA and NSF programs to observe occultations (events where a planet moves briefly in front of a star) to probe planetary atmospheres. This technique has a long and rich history of results, including the discovery of Pluto's atmosphere.

This research requires that we take cameras to areas on the Earth where the events will be observable -- for example, we just returned from Australia and New Zealand, where we observed Pluto moving in front of a bright star from seven ground-based locations. These observations require low readnoise, high frame rate cameras, like our EMCCDs.

I am concerned that our EMCCD cameras, which we purchased under a NASA grant explicitly for observing events at locations over the world, will become regulated. Specifically, I'm concerned that cameras which we have used on telescopes over the world for the past six years will no longer be allowed on foreign deployments.

This development is especially confusing because both EMCCD and InGaAs cameras are available from non-US vendors. We could, for example, buy Raptor's EMCCD and InGaAs cameras (from the UK) and have them shipped to Australia for observations. If EMCCD and InGaAs cameras cannot be taken out of the US for observations, then we cannot meet the proposed goals in our funded NASA programs.

Thank you for your attention.

Regards,
-Eliot

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Eliot F. Young, Sc.D., Principal Scientist
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==

[Email Directly To*:* *DDTCPublicComments@state.gov*]

[Subject Line, "ITAR Amendment—Category XII."]

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

My company is called Exciting Technology LLC, but my comments are mostly my own. I also am part time Technical Director for LOCI, the Ladar and Optical Communications institute. I am advising two Phd students and one masters student. I spent 40 years working for the United States Air Force. When I retired I was chief scientist for the sensors directorate, Air Force Research Laboratory. My protocol equivalent was that of a 1 star general officer. Since retiring I was vice chair of the "Seeing Photons", the National Academy of Sciences, NAS, study on passive EOIR detectors and receivers, published in 2010. I was co-chair of the Optics and Photonics: Essential Technologies for our Nation" NAS study that resulted in a fast track White House study to respond to our recommendations. I was chair of the "Laser Radar" NAS study published in 2014. Laser Radar is equivalent to Lidar and Ladar. Many of my comments result for the fact that each of these NAS studies were asked to compare the state of the art in the United States against the SOA in of the rest of the world. Therefore in Passive EO/IR Sensors, any optical systems, and in active EO/IR sensors I have been responsible within the past 5 years for comparing US SOA vs. the rest of the world SOA.

I will make comments as I go through the proposed cat 12 regulations. Because the active EO sensing study was more recent, and many of my comments are similar for active and passive sensors, I will focus my comments on the active EO sensors. I think a substantial revision of this Cat 12 work is required. As currently structured it expands the wall around exports, in contrast to my understanding of the direction. In my opinion this will hurt both US industry and the US military. For the NAS studies I have chaired it is obvious our export restrictions have not keep technology expertise in the United States, but have caused the United Sates to lose its lead in many technical areas. With respect to passive EO systems I recommend those involved with this effort read "Seeing Photons: Progress and Limits of Visible and Infrared Sensor Arrays", published by the NAS in 2010. With respect to Active EO systems I recommend those involved read "Laser radar" Progress and opportunities in Active Electro-optical Sensing", published by the NAS in 2014. For active EO systems I also recommend my Field Guide to Lidar book.

a (2)
i: "An infrared focal plane array having a peak response at a wavelength exceeding 1,000 nm"

This rule obviously dramatically expands the area covered by ITAR in direct contradiction of the guidance that caused the Cat 12 revision. There are a wide variety of FPAs commercially available with a wavelength response above 1000nm. While I could quote probably 100 products commercially available with response over 1000 nm just look on the internet. We certainly have uncooled FPAs. We have the NIR FPAs, many of which are available from overseas companies. Most of the product line of SOFRADIR in France would be covered by this restriction.

a (4) "Laser spot trackers or laser spot detection, location or imaging systems or equipment, with an operational wavelength shorter than 400 nm or longer than 710 nm, and a detection range greater than 300 m"

b (2) "Aiming or target illumination systems or equipment having a laser output wavelength exceeding 710 nm;

For both of the above areas I do not see the rational for restricting these wavelengths.

b (3) Laser rangefinders having any of the following:

(i) Q -switched laser pulse; or

Q switched lasers are very common around the world. I think this restriction will hurt US industry compared to the rest of the world, and will indirectly hurt the US military because they will end up having to buy their systems overseas rather than from US suppliers.

(ii) Laser output wavelength exceeding 1,000 nm

Lasers with output exceeding 1000 nm are very common around the world. Same comment on hurting US industry and the US military.

(5) Systems or equipment that use laser energy with an output wavelength exceeding 710 nm to exploit differential target - background retroreflectance in order to detect personnel or optical / electro -optical equipment (e.g., optical augmentation systems);

I am not sure I can think of a commercial use for OA systems, so this might be okay even though the wavelength restriction does not make a lot of sense based on state of the art around the world.

(6) Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km Note to paragraph (b)(6) :This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less

Lidar is being used around the world. It is correct that auto lidar is one of the larger coming uses. Exempting any auto lidar is a good thing. There are also widespread 3D mapping lidars. OPTEC (Canada) and Riegl (Germany) are two of the largest manufacturers. Due to ITAR controls it is not surprising the US does not have a larger manufacturer of 3D lidar. The Microsoft connect is a short range gaming system that is widespread and is essentially a lidar. Wind sensing lidars are sold world wide.
The US military has a definite need for 3D mapping systems. Continuing to discourage 3D mapping commercial lidar technology in the United States, as this paragraph does because 3D mapping technology will be beyond 200 meters, will hurt the US military.

(7)
"Synthetic aperture LIDAR or LADAR systems or equipment, having a stand - off range of 100 m or greater "

This shows a lack of understanding of what is critical in a synthetic aperture lidar. The max range of the lidar is mostly controlled by the power of the laser. More powerful lasers are widely available. Germany probably has the lead. If this line item talked about how many times better the SAL's resolution is than the diffraction limit of its real receive aperture size, or than the r_0 of the atmosphere, then this could make sense. Something like 10 times better resolution then the diffraction limit of the receive aperture, and/or 10x the diffraction limit of an aperture with a diameter equal to r_0 might make sense.

(8)
LIDAR, LADAR, or other laser range -gated systems or equipment,
as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):
(i) Systems or equipment having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft , and incorporating or specially designed to incorporate a gimbal - mounted transmitter or beam director, and specially designed parts and components therefor

(ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g.,wire, power line);

(iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geiger - mode detector array having at least 32 elements or a linear- mode detector array having at least 128 elements;

Could a Geiger mode auto-lidar have 32 or more elements, or could a linear mode auto lidar have more than 128 elements? I know from discussions with one large auto manufacturer that they will avoid any technology that has ITAR related entanglements.

It likely the full GMAPD arrays will be more expensive then auto companies want anyway, but if you could at least double these values it would increase the chances US companies could compete in the auto lidar area. For US companies to compete in 3D mapping I think you would have to allow them to use a 32 x 32 GMAPD or a 128 x 128 LMAPD, although they might be able to compete with smaller arrays. 3D mapping will want better than 5 foot range resolution, so the 100 Mhz limitation will catch 3D mappers. It would be very desirable if 3D mapping lidar develop could be encouraged in the United Sates, rather than being discouraged.

(14) Developmental lasers and laser systems or equipment funded by the Department of Defense

This is a huge expansion of the ITAR restrictions that will really hurt the US military, assuming I am right in interpreting this to say as soon as a laser company takes any DOD funding to work on a laser then that laser is caught by ITAR. This means a company cannot accept any DOD funding for lasers it is developing primarily for commercial application. It has to strictly divide its product line into military and non-military lasers. DOD will not be able to leverage commercial investment in lasers if this line stays. The Navy is currently putting laser weapons on ships as a trial, but the lasers were developed for commercial use. I wonder if the navy would be allowed to do this if this line holds. IPG might refuse to sell the lasers to DOD. Certainly their commercial business is much larger, and more profitable, than their military business.

From: Felice Laird
To: DDTCPublicComments
Subject: Question concerning Cat XII (c) proposed rule
Date: Tuesday, June 02, 2015 8:35:54 PM

Hello,

I am preparing comments for submission to State in response to the Proposed Cate XII revisions.

Specifically, I have two questions on the coverage of XII (c)(7) and (c)(8) as proposed. The title of XII indicates that Infrared Focal Plane Arrays are controlled therin. In fact, most items in Category XII (c) specifically reference infrared focal plane arrays (IRFPAs); items (c)(7) and (c)(8) are notable in that they do not. Is this as intended, or should reference to IRFPAs be made in items (7) and (8)? If an FPA used available light (not infrared) would it be "enumerated" in (7) and (8)?

The second question concerns the definition of "avalanche detector elements" in (c)(8). Does the word ELEMENTS refer to pixels of an image sensor? Do you have a working definition of avalanche detector elements?

I am working on preparing comments, and it would be helpful to have some clarity on this soon.

Thank you in advance.

Felice Laird
Export Strategies, LLC
301.229.2573

FLIR | The World's Sixth Sense™

July 2, 2015

Office of Defense Trade Controls
Department of State
Washington, DC
Emai: DDTCPublicComments@state.gov

Subject: ITAR Amendment - Category XII, RIN 1400-AD32 (Public Notice 9110)

Dear Sir/Madam,

FLIR Systems, Inc. (FLIR) is providing this document in response to the proposed revision of Category XII of the ITAR. FLIR is a world leader in the design, manufacture, and marketing of sensor systems that enhance perception and awareness. FLIR's advanced thermal imaging and threat detection systems are used for a wide variety of imaging, thermography, and security applications, including airborne and ground-based surveillance, condition monitoring, research and development, manufacturing process control, search and rescue, drug interdiction, navigation, transportation safety, border and maritime patrol, and environmental monitoring. FLIR has annual revenues of approximately $1.5B with over half of that revenue generated by sales outside of the U.S. Category XII of the ITAR has the potential to have a significant impact on the sales of FLIR's products.

TOP LEVEL COMMENT

As part of the Administration's Export Control Reform (ECR) Initiative, the rewrite of USML category XII and the companion revisions to the EAR was to establish a "bright line" between items on the USML and the Commerce Control List (CCL) by describing more precisely the articles warranting control on the USML. The objective of ECR is to protect and enhance US national security interests which includes strengthening the US industrial base. Taken together however, the proposed revision of USML Category XII and the related EAR changes would place items in normal commercial use on the USML and impose greater restrictions on items on the CCL. Over-control, as proposed in the two rules, will provide incentive for foreign customers to seek foreign, rather than US products. In the short term this reduces US control and visibility over commercial products that have potential military applications. In the long term, over-control can diminish the US night vision/thermal imaging industrial base by effectively limiting foreign markets, thereby weakening, rather than strengthening the US industrial base.

The Export Control Reform (ECR) initiative was launched with the expressed purpose of building higher walls around fewer items. This was meant to focus resources toward the most significant technologies, while enhancing our industrial base by reducing incentives for foreign manufacturers to "design-out" US-origin components in order to avoid ITAR (i.e., incorporation of ITAR components change the nature of foreign manufactured end-items from dual-use to US ITAR controlled). The ECR also had the expressed purpose of setting straightforward guidelines that would not take a team of lawyers to understand. This proposed rule is considerably more complex than the current rule and even more expansive. In FLIR's experience, US Government export regulations have driven high-tech jobs abroad and have weakened US company's ability to compete in the global marketplace. In contrast to all the other revised categories, these proposed rules do not move lower-level items that are clearly military to the CCL. Instead, they explicitly propose to place items that are in normal commercial use on the USML and impose more restrictive controls on the items proposed to remain on the CCL.

FLIR is greatly concerned that the proposal for Category XII does not reflect the expressed purpose of the ECR. The proposed draft for Category XII fails for several reasons as listed below.

- Commercial markets dominate sales of many technologies described in the Category XII draft
- Foreign availability is not adequately considered
- Actual military items are not specified in the proposal.

Therefore, FLIR recommends that these proposed rules be fundamentally rewritten after thorough and sincere collaboration with stakeholders among industry, USG, and research institutes. Now that there is a definition of "specially designed," use of this as a control parameter would be a simple and effective way to implement the principle of ECR in USML Category XII and the corresponding revisions to the EAR. If the USG continues to seek to identify technical parameters for the revised USML and EAR, using "specially designed" as the principle would achieve the ECR objectives. The broad criteria proposed are based on limits of today's commercial performance for these items rather than defining parameters of military significance. The proposal for Category XII would regulate companies to performance parameters that are simply at the edge of today's commercial market, as opposed to defining parameters of military sensitive items. The proposed approach allows for no future growth in these rapidly advancing technology areas in commercial and consumer markets. Furthermore, it will disincentivize investment by U.S. companies in emerging technology and markets.

Moreover, the proposed revisions to the USML and the EAR are inconsistent with the controls in the Wassenaar Arrangement. The USML should also align with the internationally agreed upon Wassenaar Munitions List. Commodities and components not specially designed for military purposes or on the Wassenaar Dual-Use List should be controlled under the Commerce Control List (CCL). Though still controlled under the CCL, the list controlled by the Department of Commerce allows for more flexibility on how controls are applied, and can adjust to conditions more quickly than items under the USML. EAR controls that are more restrictive than the Wassenaar Dual-Use List and the license-free treatment of Wassenaar Dual-Use items within the European Union and other allied trading partners, will further disadvantage US companies for the smaller portion of the commercial market proposed for the CCL under these rules.

This proposed EAR companion rule is equally confusing and difficult to navigate. Certain articles have greater restrictions applied without apparent logic (6A002 items have more restrictions than 6A003 items). This proposed rule places excessive increased controls on exports of dual-use products to Canada, which is a radical departure from the vast majority of items subject to the EAR. Placing greater restrictions on license exceptions such as STA, APR, and TSR is in direct conflict with the ECR objectives and result in the need to obtain more export licenses. There are numerous changes that mostly increase controls and complicate the process.

These proposed rules are not simplifying the regulations and in fact, this will be a boon to the trade compliance legal community as it will be very difficult to gain an understanding of these changes and implement process changes without specialized legal consultation. It will be particularly burdensome for small businesses as they attempt to understand the rules and may not have the resources to hire the required specialized trade compliance legal experts. This will result in demotivating companies from entering global markets and has a spiraling effect to weaken US companies and strengthen foreign competitors.

SPECIFIC COMMENTS

This document will address most of the major sections of Category XII as FLIR designs, manufactures, and markets a wide variety of products that are based on technology that could be controlled by this category.

Request For Comments (note: the questions are shortened in the responses below)

The Public Notice document requested input on seven questions. Following are responses to those questions.

1) ***The Public is asked to identify any potential lack of coverage between the Wassenaar ML (W-ML) and Wassenaar Dual-Use List (W-DUL) as a result of the Category XII (Cat XII) proposal.***

RESPONSE: FLIR is not aware of any areas that lack coverage that need to be controlled.

2) ***The Public is asked to identify any items proposed for control on the USML that are not controlled on the Wassenaar ML or DUL.***

RESPONSE:

a. Readout Integrated Circuits (ROICs) as described in (e)(4) and (e)(5) are not controlled on the W-ML or the W-DUL. In fact the Wassenaar specifically rejected a 2007 U.S.G. WA proposal to add ROICs to the M-DUL. This will be discussed in more detail in this document in the (e) section responses.
b. 6A993 products are not controlled by the W-DUL or the W-ML. This rule proposes to place controls on 6A993 products that may be incorporated into military products, which is a low-probability scenario. Further, if 6A993 products are incorporated into "true" military items, the military utility is very limited due to the "slow video" related to 6A993 articles.

3) ***The Public is asked to provide examples of control criteria that do not establish a bright line between the USML and the CCL.***

RESPONSE: There are multiple examples with specific information in this document that identify the lack of a bright line between USML and CCL items.

4) ***The stated goal of Export Control Reform (ECR) is to only control items on the ITAR that are not in normal commercial use or to assure that only items that provide the U.S. government with a critical military or intelligence advantage. The Public is asked to provide specific examples of commercial use as well as data related to foreign availability of such items.***

RESPONSE: There are numerous examples of items listed in the proposed CAT XII that are in commercial use and available world-wide.

a. Lasers covered in paragraph (b)
b. Cooled and Uncooled focal plane arrays, cameras incorporating cooled and uncooled focal plane arrays, IRFPA integrated dewar cooler assemblies (IDCAs), Gimbals, camera cores (with no shock specification), Binoculars, imaging systems, cryo-coolers, optics, electronic assemblies, ROICs and many more items.

5) ***The Public is asked to identify parameters that are unique to military users.***

RESPONSE: Where applicable or possible, military performance parameters will be identified. However, there is a basic flaw with this proposed language in trying to identify military parameters on items that are inherently dual-use. For example, infrared focal plane arrays (IRFPA) are typically designed to a general performance standard and it isn't until the IRFPA is installed into a higher-level system that the militarization occurs. The same IRFPA may be installed in a commercial thermography camera that is also installed into a thermal weapon sight.

6) ***The Public is asked to comment on the consequences of controlling items on the USML when they are also controlled on the W-DUL.***

RESPONSE: This document will discuss the foreign availability of many of the items listed on the proposed CAT XII. Later in this document we will make clear that IRFPA technology is widely available world-wide including from credible manufacturing facilities located in the EU, Middle East, and Asia (including China). Further, third party market data will be shown that demonstrates that commercial applications for uncooled products outnumber military applications by 4 to 1 world-wide. Additionally, market research data identifies that over half of all cooled detectors and products are produced outside of the U.S.

It is no surprise that given a choice for equal performance, that non-US camera and system manufacturers will choose to integrate dual-use products manufactured outside of the U.S. over products that are ITAR controlled. Many non-US manufacturers of products that incorporate IRFPAs advertise their products as "ITAR-FREE" as shown by the example of a statement made by Selex ES below. This situation places U.S. manufacturers of thermal imaging components and systems at a distinct disadvantage in the ability to compete in the global market place. Figure 1 shows the significant number of non-U.S. manufacturers of uncooled detectors that have entered the market over the last decade. These Non-U.S. detector manufacturers have relatively quickly developed manufacturing capability and are producing advanced technology.

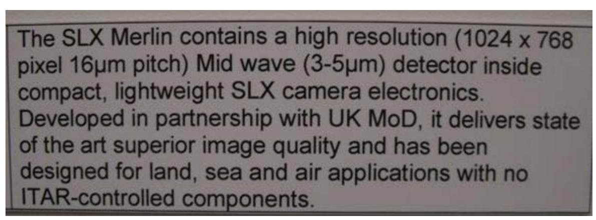
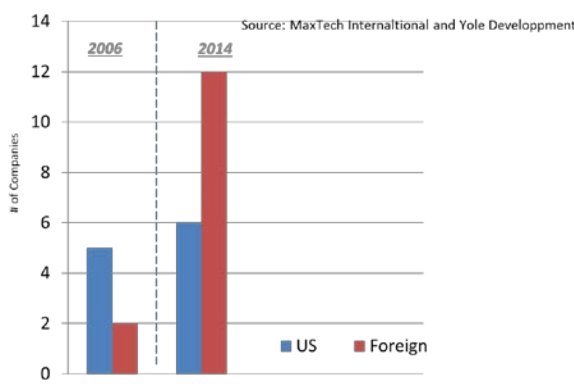

The SLX Merlin contains a high resolution (1024 x 768 pixel 16µm pitch) Mid wave (3-5µm) detector inside compact, lightweight SLX camera electronics. Developed in partnership with UK MoD, it delivers state of the art superior image quality and has been designed for land, sea and air applications with no ITAR-controlled components.

Figure 1 **The Number of Foreign UFPA Production Manufacturing Facilities Is Increasing Dramatically**



The Number and technical sophistication of foreign UFPA manufacturers has increased and will continue to do so as foreign firms take advantage of ITAR export restrictions on U.S. manufacturers. Figure 2 is a table showing by country, Microbolometer IRFPA technology currently being manufactured.

Figure 2 Companies Producing Microbolometer IRFPAs

	Number of Companies Producing Microbolometer IRFPAs								
					Source: MaxTech International				
	U.S	Japan	Israel	China	Canada	France	Germany	Korea	Turkey
Material Type									
Vanadium Oxide (VOx)	5	1	1	2	2				
Amorphous Silicon (a-Si)	1			2		1	1		
Silicon-on-Insulator (SOI)		2						1	
Titanium Oxide (TiOx)								1	
Various Uncooled Technologies				1				1	1
	6	3	1	5	2	1	1	3	1

7) ***The Public is asked to comment on several new concepts introduced in the CAT XII proposed draft***

RESPONSE:

a. Refer to (c)(2) for comments regarding using integration of an IRFPA into a package as a control parameter.
b. Refer to (c)(12) for comments regarding using integration of an IRFPA into a camera as a control parameter. And the definition of camera core proposed in the note to (c)12
c. Refer to (c)(12)(ii) for comments regarding the weapon shock load control criteria
d. Refer to (f) for comments on the proposed controls on technical data.

SPECIFIC COMMENTS TO CAT XII

(a) Fire control, weapons sights, aiming, and imaging systems and equipment, as follows:
(2) Weapon sights, weapon aiming systems or equipment, and weapon imaging systems or equipment (e.g., clip-on), with or without an integrated viewer, display, or reticle, and incorporating or specially designed to incorporate any of the following:
(i) An infrared focal plane array having a peak response at a wavelength exceeding 1,000 nm;

ISSUE: There is no distinction between “civil” weapon sights and “military” weapon sites. No military parameters are identified.

1) There are weapon sights that were specifically developed for hunters and non-military end-users.
    a. Amrasight, Zeus Pro, US http://www.armasight.com/thermal-imaging/thermal-weapon-sights/armasight-zeus-pro-336-8-32x100-60-hz
    b. FLIR, R-Series, US http://flir.com/thermoSightR-Series/
2) There are civil weapon sights available from non-US sources.
    a. General Starlight, Canada

http://www.nvoptics.com/gsci%20thermal%20imaging/thermal-imaging-systems.html

i. A note in their section regarding exports: GSCI is Canadian-owned and based company. This means that our Customers enjoy: 1. Low, "North American" prices and 2. ITAR free products, that are easily available for export. *Canada Customs export control applies, please ask us for a free consultation.

b. Pulsar, Lithuania. http://www.pulsar-nv.com/products/thermal-imaging-sights-apex/apex-xd75/

3) There are features unique to civil users as explained in this Buyers guide to help consumers purchase thermal weapon sights. http://www.nvoptics.com/documents/The%20Ultimate%20Guide%20Final_WEB.pdf
4) Weapon sights developed and used by military end-users have specific performance and environmental requirements. The US DOD is not likely to purchase these "civil" sights.

RECOMMENDATION: specify a military performance parameter or add the term "specially designed for military end-uses" to this section. Consider the export controls for civil devices applied by Wassenaar and implement similar controls for US origin products.

(b) Lasers, and laser systems and equipment, as follows:

(b)(3) Laser rangefinders having any of the following:
(b)(3)(i) Q-switched laser pulse; or
(b)(3)(ii) Laser output wavelength exceeding 1,000 nm;

ISSUE:

1) Rangefinders capable of 2^{+} km performance typically conflict with both of these requirements in (b)(3)(i) and (ii). Rangefinders for common sporting applications have performance < 2km and will be captured by the proposed controls.
2) The processes for creating a Q-switched laser pulse and for a device with a wavelength > 1000 nm are well known and widely documented.
   a. Q-Switched laser pulse: implies rangefinders operating under well-known principles of time of flight of single laser pulse
   b. Wavelength over 1000 nm: Rangefinder wavelengths are commonly between 1500 – 1600 nm due to eye-safety considerations as well as common laser technologies to generate these wavelengths
3) Rangefinder devices utilizing both of these principles are readily available for purchase off-the-shelf from foreign sources
4) The proposed language will prevent domestic companies from competing against these foreign companies for non-US markets
5) Rangefinders have non-military applications: Determination of flight altitudes / aircraft height, border monitoring systems, surveying, mapping, construction, non-military aviation and transportation, position determination of moving targets, law enforcement, etc.

Non-US Sources:

1) Cassidian (France) - formerly Zeiss (Germany) : LP16, LP17, LP18, LP19, 1540 nm; Er:glass Q-Switched laser20km capabilities; diode and lamp pumped; > 1Hz capabilities http://www.idssi.com/products/lrf/lp/default.aspx#.VYiQ2kbxTP0
2) Jenoptik (Germany): ELEM, ELEM-DP 1540 nm; Er:glass Q-Switched laser 20km capabilities; diode and lamp pumped; 10Hz capabilities

http://www.jenoptik.com/en_40137_elem_solid-state-laser_rangefinders

3) Laserdyne (Australia): GSLR-2K, HPCL-10KO, L5LGH, L5LUR, HPCL-20KO, L20LC, L-GM5, L-GM20, L-NAV30K, 1570 nm; Nd:YAG with OPO; Q-Switched laser. Range capabilities out to 30km; diode and lamp-pumped; Rep rates as high as 30Hz
http://www.laserdyne.com.au/rangepro/models/
4) Newcon Optik (Canada): LRF MOD 15HF, 25HF, 25HFLC, LRB12K, LRB 12Knight, LRB 20,000C. 1570 nm; Nd:YAG with OPO; Q-Switched laser. Range capabilities out to 30km; Rep rates as high as 15Hz 1550 nm and 1060 nm direct diode laser rangefinder binoculars
http://www.newcon-optik.com/laser.html
5) Meprolight (Israel): MEPRO LRF 15-02, 16-52, 16-54, 16-61, 16-70, 17-52, 20-70, 1540 nm; Er:glass Q-Switched laser. 20km capabilities; 3Hz capabilities
http://www.meprolight.com/default.asp?catid={EC52CE88-DC3D-4C79-8E0A-5F06554CDED0}
6) ITL Optronics [Elbit Systems] (Israel): Ranger 12, Ranger 4B, Cobra, 1550 nm; Direct diode. 1540 nm; Er:glass Q-Switched laser. 20km capabilities; diode-pumped; 1Hz capabilities
http://www.premierelect.co.uk/laser-rang-finder-optronics-c-28.html
7) Fontona (Slovenia): ESLRF, Metrix, LRM-E2, 1540 nm; Er:glass Q-Switched laser. 20km capabilities; 1/3 Hz capabilities
http://www.fotona.com/en/non-medical/defense/rangefinders/
8) Noptel (Finland): LRF-200, LRF-240, LRF-500, LRF-750, 1550 nm; direct diode. 20km capabilities; 10Hz
http://www.noptel.fi/eng2/LongDistance/index.php?doc=6_downloads/3_brochures

RECOMMENDATION: specify a military performance parameter or add the term “specially designed for military end-uses” to this section.

(8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):

ISSUE: The articles described in this section are available from non-US sources. The parameters are very broad.

1) Riegl (Austria): LMS-Q780, LMS-Q1560, 1064 nm
Both appear to be capable of wire detection (12-b-8-ii)
http://www.riegl.com/nc/products/airborne-scanning/
2) Airborne Hydrography AB (Sweden): HawkEye III “Infrared”. May be capable of wire detection (12-b-8-ii)
http://www.airbornehydro.com/hawkeye-iii
3) Leica Geosystems (Switzerland): ALS80. May be capable of wire detection (12-b-8-ii)
http://www.leica-geosystems.us/en/Airborne-LIDAR_86814.htm
4) Teledyne Optech (Canada): Orion, Galaxy, Pegasus. 1541 nm, 1064 nm
“Coupled with exceptional small target detection capability, Orion C provides complete collection confidence of all overflown transmission and distribution lines, irrespective of cable size and coatings.” (12-b-8-ii, possibly 12-b-8-i)
http://www.teledyneoptech.com/index.php/products/airborne-survey/lidar-systems/
5) Elbit Systems (Israel): Sword. “Obstacle Warning System” for helicopters
Limited information on website, but may include wire detection (12-b-8-ii)
Likely adaptable to military ground vehicles (12-b-8-vi)

http://www.elbitsystems-us.com/airborne-solutions/products-sub-systems/obstacle-detection-and-avoidance

RECOMMENDATION: Coordinate the control of articles in this section with the Wassenaar Munitions List.

(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:

ISSUE: The definitions for the various types of components are confusing and appear to be a "catch all." For example the following terms are used;
IRFPA, Photon Detector, microbolometer detector, multi-spectral infrared focal plane array (IRFPA), one-dimensional photon detector IRFPA, two-dimensional photon detector IRFPA, microbolometer IRFPA, charge multiplication focal plane arrays, charge multiplication IRFPA. What is Night Vision? What are accessories? What is the difference between a camera and a core?

RECOMMENDATION: Establish clear definitions and names and use the names consistently throughout the document.

(C)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;

ISSUE: The concept of a permanent encapsulated sensor assembly is 1) not well defined and 2) is not a bright line parameter to distinguish an ITAR item from a CCL item.

IRFPAs are packaged using various methods depending on the type of detector. Microbolometer IRFPAs/detectors are typically packaged in a sealed vacuum device. Photon detector IRFPAs may be packaged in different methods depending on many factors. A photon detector may eventually become packaged in a sealed vacuum assembly however; those steps have little to do with whether the device is military in nature. It's not clear why the "permanent encapsulated sensor assembly" is used as a military parameter. One can speculate that the USG is concerned about either reverse engineering of IRFPAs, diversion of IRFPAs, or both.

Permanent encapsulation will not eliminate reverse engineering by an entity that is knowledgeable, funded and motivated. However, reverse engineering is a concern for all technologies and companies such as FLIR institute extensive measures to protect intellectual property.

The motivation to purchase a camera assembly with the purpose to remove the IRFPA for diversion into a military system isn't practical. The availability of IRFPAs world-wide and the extra cost of purchasing a camera to harvest the IRFPA then dispose of the camera assembly isn't cost effective or practical on any type of a large scale basis. It is possible that there might be a one-off situation where an IRFPA is removed from a commercial camera, but it is unlikely to occur in volume.

In summary, FLIR is concerned that the encapsulation of an IRFPA is being used as a distinguishing parameter for a military item, which has no bearing on its military utility. Further, we are concerned that the definition of a permanent encapsulation sensor assembly is not sufficiently defined.

RECOMMENDATION: Remove this packaging concept as criteria for distinguishing a military item and add language that CAT XII will control FPAs specially designed for military applications.

> ***Note 1 to paragraph (c)(2): This paragraph does not control lead sulfide or lead selenide IRFPAs having a peak response within the wavelength range exceeding 1,000 nm but not exceeding 5,000 nm and not exceeding 16 detector elements, or pyrolectric IRFPAs with detectors composed of any of the following or their variants: triglycine sulphate, lead-lanthanum zirconium titanate, lithium tantalite, polyvinylidene fluoride, or strontium barium niobate.***

ISSUE: This exclusion seems designed to allow lower performance solutions. However, this note is lacking clear performance parameters but instead specifies detector materials deemed to not be relevant for military uses. FLIR's concern is that, as various detector materials mature, performance is likely to improve and yet the devices won't be controlled. This phenomenon may actually drive sensor material development efforts by organizations wishing to avoid ITAR controls. As an example, prior to 2005 amorphous silicon (a-Si) was not export controlled by the US or by Wassenaar. However, over time a-Si performance improved such that its performance became equal to other microbolometer materials such as vanadium oxide (VOX). In 2003 - 2005, the US DOD expended significant and successful effort to place controls on a-Si FPAs at the Wassenaar level as acknowledgment that a-Si performance improved[1]. We believe excluding certain detector materials as per this proposal will have a similar outcome and does not acknowledge that various detector materials mature over time.

RECOMMENDATION: It is not possible to establish performance parameters relevant to military requirements. Currently, only pixel count is established as a military parameter. However, the pixel count "bright line" for US controls has been exceeded by non-US sources and these foreign manufactured large FPAs are being incorporated into non-military systems. Focal plane arrays should be ITAR controlled ONLY when specially designed for military applications.

Note 2 to paragraph (c)(2): For controls on readout integrated circuits (ROICs), see paragraphs (e)(4) and (e)(5) of this category.

ISSUE: NOTE 2 to paragraph (c)(2) should not be in this section. ROICs are addressed in section (e). Referencing ROICs in section (c) is confusing as there are potentially many other components that could also be referenced in this section and it's not clear why ROICs are highlighted.

RECOMMENDATION: Remove Note 2 since it only adds to confusion related to navigating the CAT XII.

> ***(C)(3) One-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 640 detector elements;***

ISSUE: One-dimensional photon detector IRFPAs with greater than 640 detector elements are available from non-US sources. Placing ITAR controls on items that are in commercial use and available from

[1] FRN Vol. 70, 135 / July 15, 2005. Several key changes were made by this notice; a-Si Detectors were controlled, and the definition of a camera, the automotive exception, and the 9Hz exclusion were all implemented.

foreign sources is in conflict with the ECR guiding principles. Many one-dimensional photon IRFPAs are used for non-military telecommunication and spectroscopy applications.

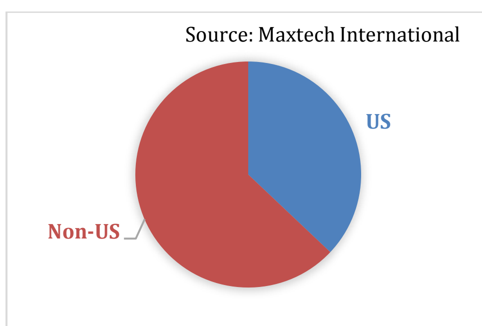
1) The number of detector elements is not a criterion that delineates dual-use and military one-dimensional photon detector IRFPAs
2) The detector is a dual-use device
3) The pixel count constraint has no specific military significance
4) Similar devices are listed on the Wassenaar DUL and not on the Wassenaar "Munitions List." Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
5) There are foreign available dual-use products, for example:
    a. Xenics Xlin-17-3000 http://www.xenics.com/en/xlin-17-3000
    b. Hamamatsu http://www.hamamatsu.com/jp/en/product/category/3100/4005/4208/4121/index.html

RECOMMENDATION: Remove one-dimensional photon IRFPAs from the list, specify a military performance parameter, or add the term "specially designed for military end-uses" to this section.

(C)(4) Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 256 detector elements;

ISSUE: Two-dimensional photon IRFPAs are widely available world-wide. According to the market analysis data from Maxtech International[2], nearly two-thirds of military IRFPAs consumed worldwide are made by non-US suppliers (mainly based in France, Israel, the UK and Germany, but also in Sweden, South Korea and China). See Figure 3.

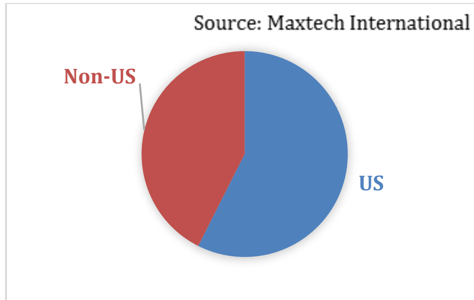
Figure 3 **Cooled IRFPA sources for military applications (US vs. Non-US)**



2 Maxtech International, has specialized in analyzing worldwide infrared markets for over the last 25 years. This company makes regular site visits to all suppliers of infrared detectors worldwide and publishes a series of market research reports on commercial, dual-use, and military infrared markets. These reports have been purchased by most major suppliers of infrared detectors and systems, as well as the U.S. Army. In addition, Maxtech has carried out a major capabilities analysis of infrared detector manufacturers for the U.S. Air Force.

Almost half of all commercial and dual-use applications for photon IRFPAs are being satisfied by non-US suppliers of cooled IRFPAs. See Figure 4.

Figure 4 **Cooled IRFPA sources for COMMERCIAL applications (US vs. Non-US)**



It should be noted that Wassenaar controls many "cooled camera cores" and integrated IRFPA dewar cooler assemblies (IDCA) as 6.A.3.b.4.a dual-use items unless specifically designed for military applications. This is relevant to item 4) in the Request for Comments which states that the US Government does not want to inadvertently control items on the ITAR that are in normal commercial use. The Request for Comments also states that only items that provide the US with critical military or intelligence advantage should be controlled by the ITAR. Since these items are in normal commercial use and due to the significant market share of the non-US manufacturers, these items are not unique to the US.

Non-US Sources

1) SCD, Israel, 1920x1536 InSb, MWIR. http://www.eurosatory.mod.gov.il/pdfs/SOD_SCD.pdf
2) Sofradir, France. 640x480 SWIR FPA. http://www.sofradir.com/product/cactus-640-sw-2/
3) SCD, Israel. 640x480 SWIR FPA. http://www.scdusa-ir.com/cardinal-640/?doing_wp_cron=1435271330.2543458938598632812500
4) Selix, UK. 1280x720 MCT http://www.selex-es.com/product-portfolio/optronics-system/thermal-detectors
5) IR Nova, Sweden. 640x480 T2SL FPAs. http://www.ir-nova.se/products-mwir/

RECOMMENDATION: Remove two-dimensional photon IRFPAs from CAT XII, or specify a military performance parameter, or add the term "specially designed for military end-uses" to this section.

(c)(5) Microbolometer IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 328,000 detector elements;

ISSUE: Microbolometer IRFPAs in a permanent encapsulated assembly having greater than 328,000 elements are available from multiple non-US sources and are integrated into non-military products. Figure 1 highlights the significant number of Non-US UFPA manufacturers that have entered the market over the last decade.

Figure 5 Commercial vs. Military UFPA Market (Worldwide)

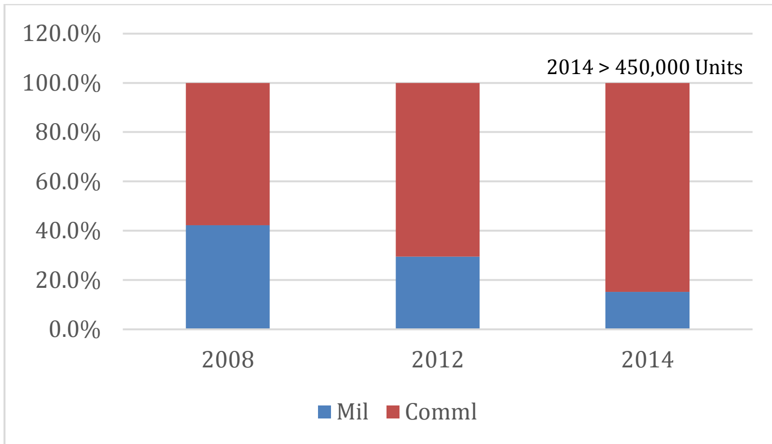
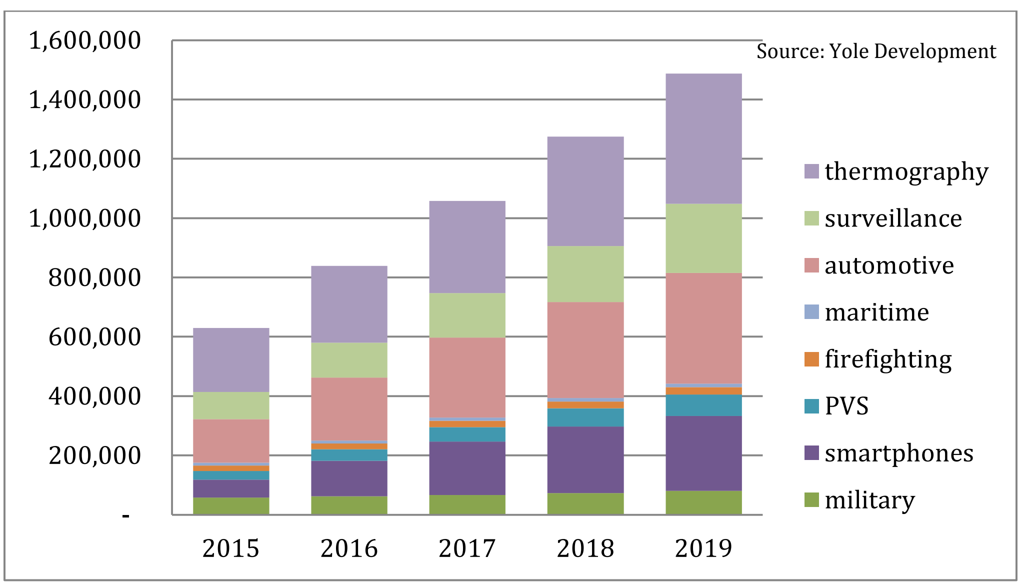


Figure 5 emphasizes the continued growth of the commercial market for Microbolometer IRFPAs and products and it also highlights that commercial sales far exceed military sales.[3] Further, it's relevant to note that the Maxtech 2014 data shows that the number of UFPA devices manufactured world-wide increased by over 40% between 2013 and 2014. This growth in units manufactured is driven by the increasing commercial demand for uncooled technology. Figure 6 provides a view of the markets that are expanding world-wide. Further, it is clear from this data that the requirements by the military for uncooled Microbolometer IRFPAs represents a fraction of the demand and promises little growth.

Figure 6 UFPA Camera Forecast by Market



[3] Data shown in Figures 2, 3, 4 and 5 is from Maxtech International 2015 Report "The World Market for Commercial and Dual-Use Infrared Imaging and Infrared Thermometry Equipment"

Placing ITAR controls on items that are in commercial use and available from non-US sources is contrary to the ECR guiding principles. The consequences of controlling this technology under the ITAR will be devastating to the US manufacturing base as OEMs will choose to source UFPAs from companies that are not encumbered by ITAR controls.

Performance is rapidly improving and commercial manufacturing techniques such as wafer-level-packaging and pixel-level-packaging, are greatly reducing manufacturing costs and reducing prices of IRFPAs. Much of this innovation is driven from commercial demand rather than military requirements. As shown above in Figures 1 and 2 a growing number of the commercial manufacturers are non-US companies. Placing ITAR controls on dual-use technology will have the unintended effect of strengthening non-US companies at the expense of US manufacturers. Overseas customers will avoid ITAR controls by turning to those offshore producers; US producers will lose economies of scale, and in the end America's military will become dependent on non-US sources for this vital technology. The US Satellite and LCD industries are examples of exactly this situation occurring which resulted in the product development and manufacturing efficiencies and expertise moving outside of the US.

Non-US Sources:

1) Semi-Conductor Devices (SCD), Israel, 1024 x 768 VOX http://www.scdusa-ir.com/bird-xga/
2) ULIS, France, Pico 1024 x 768 a-Si UFPA. http://www.ulis-ir.com/index.php?infrared-detector=gen2pico1024
3) North Guang Wei Technologies (GWIC), China, 640x480 VOX microbolometers. http://www.gwic.com.cn/en_productdetail.html?id=21
4) Dali, China 640x480 a:Si UFPA. http://www.dali-tech.us/products/dlc640-60.html
5) i3 Systems, Korea. http://www.i3system.com/eng/n_product/product101.html

RECOMMENDATION: Remove Microbolometer IRFPAs from the ITAR and place control of the products and technology under the Department of Commerce (DOC) Export Administration Regulations (EAR). This will match the controls implemented by the Wassenaar DUL. It really is not possible to identify performance parameters that are strictly military for Microbolometer IRFPAs. The militarization occurs once the device is integrated into a higher level assembly which has been specially designed for military applications.

(c)(6) Multispectral IRFPAs in a permanent encapsulated sensor assembly, having a peak response in any spectral band within the wavelength range exceeding 1,500 nm but not exceeding 30,000 nm;

ISSUE: There are DOD programs like iFLIR using the Dewar Cooler Bench (DCB) with the Variable Aperture Coldshield which are clearly ITAR. However, devices and systems for this program will be "specifically designed for mil use" and not used commercially.

RECOMMENDATION: specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

ISSUE: This language doesn't acknowledge foreign availability from Semi-Conductor Devices (SCD) in Israel, Sofradir in France, AIM in Germany and other sources in Asia. Additionally there are no suggested or intended use restrictions or performance restrictions to allow for the growing number of commercial applications of this technology.

Foreign Availability:

1) Sofradir has a large family of IDCAs available on a commercial basis. http://www.sofradir.com/category_product/mwir-detectors/
2) Wuhan JoJo Technology, China. http://johotek01.en.made-in-china.com/product/HqanJQLcaCVd/China-Mwir-Cooled-Thermal-Imaging-Module.html
3) Selex ES cooled MWIR IDCA http://www.selex-es.com/-/erica_ff-1
4) AIM HiPIR 640 MWIR IDCA http://www.aim-ir.com/en/main/products/modules.html
5) I3 Systems, S. Korea, 640 InSb and MCT IDCAs. http://www.i3system.com/eng/n_product/product101.html
6) SCD, Israel, large family of InSb IDCAs. http://www.scd.co.il/

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(9)(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

ISSUE: Cryocoolers are widely available from non-US sources and are in normal commercial use. Restriction on 218K temp and 3000 hours doesn't acknowledge foreign availability from AIM, Thales, Ricor (Israel), and companies in China and Korea. Reference section (e)(7)(i) for a list of cryocoolers available from non-US sources

RECOMMENDATION: Remove cryocoolers from the ITAR unless specially designed for military end-uses.

(c)(9)(ii) Active cold fingers;

ISSUE: All IDCAs have active cold fingers.

RECOMMENDATION: Remove from the ITAR unless specially designed for military end-uses.

(c)(9)(iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category;

ISSUE: As stated above, many items proposed for control in (a), (b), and (c) are dual-use items. Controlling all dewars as ITAR items when they are not designed for military applications will be overly restrictive.

RECOMMENDATION: Remove from the ITAR unless specially designed for military end-uses.

(c)(10) Gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 200 microradians, and specially designed for articles controlled in this

subchapter;

ISSUE: Stabilization is not a military parameter.

1) Critical military parameters are a combination of objectives for a given mission.
    a. The ability to detect, recognize, and identify certain objects at specified ranges
    b. Features such as laser designators used to direct weapons
    c. Type of platform e.g., UAV, fixed wing, rotary, high speed crafts
2) Gimbals are used for many non-military end-uses
    a. Agricultural
    b. Power line monitoring
    c. Search and rescue
    d. Law enforcement
3) There is extensive availability from non-US sources
    a. Wescam, extensive range of airborne stabilized platforms. http://www.wescam.com/index.php/products-services/airborne-surveillance-and-reconnaissance/
    b. PV Labs, extensive range of airborne stabilizied platforms, advertise "ITAR FREE", Canada http://www.pv-labs.com/
    c. Controp, extensive range of airborne stabilized platforms, Israel http://www.controp.com/category/long-range-payloads
    d. SWESystems, airborne stabilized platforms, Sweden http://www.swesystem.se/assets/300-triple---produktblad.pdf
    e. Airbus, France/South Africa http://www.defenceandsecurity-airbusds.com/en_US/web/guest/leo_iii_hd
    f. Safran, extensive range of airborne platforms, France http://www.sagem.com/aerospace/helicopters/airborne-optronics-helicopters/electro-optical-systems-eos

RECOMMENDTION: Specify military performance parameters, or military specific features such as laser designation for weapons, or add the term "specially designed for military end-uses" to this section.

(c)(11) Gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 100 microradians;

ISSUE: Stabilization is not a military parameter.

1) Critical military parameters are a combination of objectives for a given mission.
    a. The ability to detect, recognize, and identify certain objects at specified ranges
    b. Features such as laser designators used to direct weapons
    c. Type of platform e.g., UAV, fixed wing, rotary, high speed crafts
2) Gimbals are used for many non-military end-uses
    a. Agricultural
    b. Power line monitoring
    c. Search and rescue
    d. Law enforcement
3) There is extensive availability from non-US sources

a. Wescam, extensive range of airborne stabilized platforms. http://www.wescam.com/index.php/products-services/airborne-surveillance-and-reconnaissance/
b. PV Labs, extensive range of airborne stabilizied platforms, advertise “ITAR FREE”, Canada http://www.pv-labs.com/
c. Controp, extensive range of airborne stabilized platforms, Israel http://www.controp.com/category/long-range-payloads
d. SWESystems, airborne stabilized platforms, Sweden http://www.swesystem.se/assets/300-triple---produktblad.pdf
e. Airbus, France/South Africa http://www.defenceandsecurity-airbusds.com/en_US/web/guest/leo_iii_hd
f. Safran, extensive range of airborne platforms, France http://www.sagem.com/aerospace/helicopters/airborne-optronics-helicopters/electro-optical-systems-eos
g. IAI, extensive range of airborne stabilized platforms, Israel http://www.iai.co.il/Sip_Storage//FILES/5/41025.pdf

RECOMMENDTION: Specify military performance parameters, or military specific features such as laser designation for weapons, or add the term “specially designed for military end-uses” to this section.

Note to paragraph (c)(11): This paragraph does not control gimbals containing only a non-removable camera payload operating exclusively in the visible spectrum (i.e., 400 nm to 760nm)

ISSUE: The intent is not clear. Rather than specify a technology, i.e., visible cameras, the intended end-use or performance parameter must be identified. It is possible that a visible camera could be used for a military end-use depending on other factors. This language will control television broadcast cameras installed in gimbals used for traffic monitoring or filming.
There are commercially available systems from non-US companies which have interchangeable cameras. Interchangeability of cameras is a common requirement and avoids the need for a filming company or local news channel from acquiring multiple gimbal systems rather than a system with interchangeability options.

1) Dynamic Perspective, Broadcast platforms Switzerland http://dynamicperspective.com/dynax5/overview/
2) SWESystems, Broadcast platforms Sweden. http://www.swesystem.se/broadcast.html
3) Shotover, 6-axis stabilized platforms, New Zealand. Advertise “NO ITAR or EAR Controls” http://www.shotover.com/k1

RECOMMENDATION: Remove this note and provide military parameters in (c)(10) and (c)(11).

(c)(12) Infrared imaging camera cores (e.g., modules, engines, kits), and specially designed electronics and optics therefor, having any of the following:

ISSUE: There are multiple concerns with this language; definitions are required and the reference to electronics and optics is confusing in this section. Optics and electronics are covered under section (e) Components and therefore it isn’t logical to list just a couple of components in this section.

The definition of "infrared imaging camera cores" is not clear. The Note to paragraph (c)12 states: *The articles controlled by this paragraph have sufficient electronics to enable as a minimum the output of an analog or digital signal once power is applied.* This definition is very similar to the definition of camera in the EAR. Note 1 to 6A003.b states: *Imaging cameras described in 6A003.b.4 include "focal plane arrays" combined with sufficient "signal processing" electronics, beyond the read out integrated circuit, to enable as a minimum the output of an analog or digital signal once power is supplied.*

The EAR definition of Imaging Camera has been in place and implemented as a term understood by industry and confirmed through the State Department Commodity Jurisdiction (CJ) process. The Wassenaar DUL has also adopted the EAR definition for Imaging Camera. The CAT XII term introduces new terms called "cores, modules, engines, and kits" however, the CAT XII definition for "infrared imaging camera cores" appears to be the same as the EAR definition for "Imaging Camera."

It is not clear why the ITAR is creating a new term called "cores, modules, engines, and kits" rather than use the existing definition of "imaging cameras" used in the EAR and Wassenaar.

RECOMMENDATION: The CAT XII should use definitions for "imaging camera" that are common with the EAR and the Wassenaar.

(c)(12)(ii) Output imagery when subject to more than 20 weapon shock load events of 325g for 0.4 ms and a microbolometer IRFPA having greater than 111,000 detector elements;

ISSUE: This language attempts to restrict the use of a camera with greater than 111,000 detector elements (pixels) from being used for a weapon sight. The concern is that insufficient technical parameters have been identified and that there has been no consideration of foreign availability.

1) The military weapon shock specification for a thermal weapon sight is much more involved than the few parameters listed. This link represents the type of requirements for a military thermal weapon sight as specified for the Squad Thermal Sight (STS) system. https://www.fbo.gov/index?s=opportunity&mode=form&id=d8a51751cb529883b80cb9203299fb1a&tab=core&tabmode=list&=

   Extensive design, testing, and validation must be accomplished in order for a camera to survive the harsh environment of a thermal weapon sight. The STS solicitation is a common example of requirements for cameras integrated into thermal weapon sights and highlights the need for items to be "specially designed" for military applications in order to be considered for purchase by the US Navy.

   a. There are commercial requirements for cameras to survive the shock load that results from normal use of a camera. It is common for consumer thermography and industrial cameras to have a requirement to survive a 2 meter drop test. Underwriter Laboratories (UL) has requirements for consumer and industrial products to survive shock as a result of drop tests. http://ulstandardsinfonet.ul.com/tocs/tocs.asp?fn=0294.toc
   b. Consumer point and shoot cameras and cell phones have shock specifications that exceed the 325g shock load specified in this draft. For example, the Panasonic FT2 consumer camera is tested to MIL-STD 810F Method 516.5- for Shock http://www.dpreview.com/articles/9043332764/panadmcft2#specs. There are many consumer

point and shoot cameras on the market that have been ruggedized to meet the needs of adventure seekers.

c. Thermal imaging cameras (TIC) used for civil firefighters must survive a 2 to 5 meter drop which generate a shock load between 600g's to 1,500g's. NFPA 1801 provides the rigorous testing required for TICs. http://www.nfpa.org/codes-and-standards/document-information pages?mode=code&code=1801. Manufacturers of these systems find that the environmental protections that allow survival of the product during drop tests or extreme heat experienced by firefighters, occurs at the system level. Significant design and testing is required for these cameras to meet the NFPA requirements.

2) There is significant foreign availability of Microbolometer IRFPA imaging cameras that exceed the shock specification as well as the 111,000 pixel limit. Figure 7 lists a sample of cameras available from non-US manufacturers. Numerous manufacturers in the EU produce cameras with 786,000 pixels. Further, there are camera manufacturers in Asia (including China), the EU, the Middle East that commercially provide cameras that exceed the 111,000 pixel count without regard to a shock load specification.

Figure 7 Microbolometer IRFPA Cameras Available From Non-US Sources

Model	MFG	Country	Detector Type	Format	Web Link
CX640	COX	S. Korea	Uncooled	640x480	http://coxcamera.com/products/cx320cx640/
CX600	COX	S. Korea	Uncooled	640x480	http://coxcamera.com/products/cx300cx600cx1000/
TC640	ULIRvision	China	Uncooled	640x480	http://ulirvision.en.alibaba.com/product/1708476949-221296359/Thermal_Imaging_Core_TC640.html
SMIR 11X	Sunma IR Tech	China	Uncooled	640x480	
ATOM 1024	Sofradir EC	US/France	Uncooled	1024x768	http://www.electrophysics.com/DbImages/SofEC-Atom1024-v23.pdf
MicroCAM 1024 HD	Thermotecknix	UK	Uncooled	1024x768	http://www.thermoteknix.com/products/oem-thermal-imaging/microcam-1024hd-thermal-imager/
IR-TCM1024	Jenoptik	Germany	Uncooled	1024x768	http://www.jenoptik.com/en-ir-tcm-hd-1024
IR121D	Guide	China	Uncooled	640x480	http://www.wuhan-guide.com/en/Products/CVS/255.aspx
JIR-UL-623	Xi'an Gatherstar	China	Uncooled	320x240	
D-840 - module	Dali	China	Uncooled	640x480	http://translate.google.com/translate?hl=en&sl=zh-CN&u=http://www.dali-tech.com/products/d840-122.html&prev=search
UTCC640	Beijing Hamilton	China	Uncooled	640x512	http://hamilton-tech.company.weiku.com/item/Uncooled-thermal-camera-core-640-13582768.html
HX3220i 640x480/12	NEC	Japan	Uncooled	640x480/12	
EyeR 640	Opgal	Israel	Uncooled	640x480	http://www.opgal.com/DEFENSE/DefenseProducts/ThermalCores/EyeR64017u.aspx
Thermcore 121	Guide Infrared	China	Uncooled	640x480	http://www.wuhan-guide.com/en/Products/CVS/255.aspx
XTM 640	Xenics	Belgium	Uncooled	640x480	http://www.xenics.com/en/xtm-640

3) This requirement will be a significant deterrent for US companies competing in international markets. Camera customers will be concerned that the drop shock will result in fragile cameras that can't be used in normal commercial/industrial use.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards.

(c)(12)(iii) A microbolometer IRFPA described in paragraph (c)(2) of this category having greater than 328,000 detector elements, or a microbolometer IRFPA described in paragraph (c)(5) of this category;

ISSUE: There are no military parameters listed only number of pixels. As shown in Figure 7, there are cameras available from non-US manufacturers that incorporate Microbolometer IRFPAs with over twice the number of pixels as included in this language. Placing ITAR controls on items that are in commercial use and available from non-US sources is contrary to the ECR guiding principles. The consequences of controlling this technology under the ITAR will be devastating to the US manufacturing base as OEMs will choose to source cameras with Microbolometer IRFPAs from companies that are not encumbered by ITAR controls. Based on the data presented in Figures 5 and 6 there is significant demand forecasted for Microbolometer IRFPA products and US manufacturers must be encouraged, not restricted, from participating in this global market.

RECOMMENDATION: Move control of Microbolometer IRFPAs to the EAR. Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(12)(iv) An IDCA described in paragraph (c)(9) of this category, or IDCA parts or components described in paragraph (e)(7) of this category;

ISSUE: There are no military parameters listed. This proposed language captures dual-use cameras that use IDCAs.

1) IDCAs are widely available from non-US sources as discussed under the comments in (c)(9) above.
2) There are dual-use cooled cameras that are captured by this rule. End-uses for dual-use cooled cameras include: gas imaging, hyperspectral imaging, spectroscopy, and security and surveillance.
3) As with other dual-use items, many of these items are controlled on the Wassenaar DUL and not on the Wassenaar "Munitions List." Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products that incorporate IDCAs, for example:
    a. Opgal Eye-C-Gas http://www.opgal.com/portals/0/pdf/eyecgas_27.11.2012_small.pdf
    b. Telops Hyper-Cam Methane http://www.telops.com/en/hyperspectral-cameras/hyper-cam-methane
    c. Opgal Vumii Sii XR Long Range Thermal Camera http://www.opgal.com/SECURITY/SecurityProducts/ThermalCameras.aspx
    d. Cantronics Cooled Thermal Imaging Security Cameras http://www.cantronics.com/thermal-cameras/144
    e. Thales Suzie Long-Range Thermal Imager (advertises "ITAR Free"). https://www.thalesgroup.com/sites/default/files/asset/document/suzie_a4_en_032014_ref_041a.pdf

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(12)(v) A one-dimensional photon detector IRFPA described in paragraph (c)(2) of this category having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm and greater than 640 detector elements;

ISSUE: The intended article is not well defined.

RECOMMENDATION: Delete this provision or provide a clear description of the intent.

(c)(12)(vi) A one-dimensional or two-dimensional photon detector IRFPA described in paragraph (c)(2) of this category having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm and greater than 256 detector elements;

ISSUE: The intended article is not well defined.

RECOMMENDATION: Delete this provision or provide a clear description of the intent.

(c)(12) (vii) A one-dimensional photon detector IRFPA described in paragraph (c)(3) of this category;

ISSUE: This rule inadvertently captures dual-use cameras that use one-dimensional photon detector IRFPAs.

1) There are dual-use infrared linescan cameras that are captured by this rule. Applications for linescan cameras include: portable thermography, industrial and scientific R&D, predictive and preventive maintenance, building inspection. Following are examples of dual-use cameras that are captured by the rule:
   a. Sensors Unlimited http://www.sensorsinc.com/products/linescan-cameras/
2) Constraining products based on the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar DUL and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
   b. Xenics Lynx-1024-CL http://www.xenics.com/en/camera/lynx-1024-cl

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(12)(viii) A two-dimensional photon detector IRFPA described in paragraph (c)(2) or (4) of this category having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm, and greater than 111,000 detector elements

ISSUE: This proposed rule inadvertently captures some dual-use SWIR cameras that use two-dimensional photon detector IRFPAs.

1) There are dual-use infrared InGaAs cameras that are captured by this proposed rule. Applications for dual-use InGaAs cameras include: spectroscopy, semiconductor inspection and

DWDM optical performance monitoring. Examples of dual-use cameras that are captured by the proposed rule include:

   a. Sensors Unlimited Mini SWIR http://www.sensorsinc.com/products/detail/mini-swir-jsx-snapshot-camera-60-fps
   b. FLIR Tau SWIR http://www.flir.com/cores/display/?id=51890

2) Constraining products based on the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar DUL and not on the Wassenaar "Munitions List." Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
   a. Xenics BobCat 640 http://www.xenics.com/en/bobcat-640-gige
   b. Raptor Owl 640 http://www.raptorphotonics.com/product/owl-640-analog-33
   c. SCD InGaAs 640 http://www.scdusa-ir.com/ingaas/

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(C)(12)(ix) A two-dimensional photon detector IRFPA described in paragraph (c)(4) of this category having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm

ISSUE: This proposed rule captures dual-use cooled cameras that use two-dimensional cooled IDCAs.

1) There are dual-use infrared research cameras, gas-imaging and security that are captured by this proposed rule which have received dual-use determinations through the Commodity Jurisdiction process. Applications for infrared research cameras include: Non-destructive testing, manufacturing monitoring, gaseous cloud studies. Applications for gas-imaging cameras include: methane emissions monitoring, leak detection, pollution monitoring, flare measurement, and standoff emission characterization of smokestacks. Applications for security and surveillance include border security and facility monitoring. Following are examples of cameras determined to be dual-use by DDTC that are captured by the proposed rule:
   a. FLIR GF300/320 Infrared Cameras http://www.flir.com/ogi/display/?id=55671
   b. Sofradir EC IRE-320M Camera http://www.thermal-cameras.com/th-mwirs.html
   c. FLIR a6700sc Science Camera. This camera incorporates a 640x480 InSb IDCA. http://www.flir.com/science/display/?id=67022
2) Constraining products based on the pixel count and wave-length has no specific military significance.
3) These items are controlled on the Wassenaar DUL and as 6A003.b.4.a by the Commerce Department. Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices. Confusion will result and the number of CJs will likely increase.
4) There are foreign available dual-use products, for example:
   a. Xenics Onca-LWIR-MCT-384 http://www.xenics.com/en/onca-lwir-mct-384
   b. Telops TX-IR http://www.telops.com/en/infrared-cameras/ts-ir-thermal-scientific-ir-camera
   c. Opgal Vumii Sii XR Long Range Thermal Camera http://www.opgal.com/SECURITY/SecurityProducts/ThermalCameras.aspx

d. Cantronics Cooled Thermal Imaging Security Cameras http://www.cantronics.com/thermal-cameras/144
e. Thales Suzie Long-Range Thermal Imager (advertises "ITAR Free"). https://www.thalesgroup.com/sites/default/files/asset/document/suzie_a4_en_032014_ref_041a.pdf

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(c)(13)(ii) Binoculars, biocculars, monoculars, goggles, or head or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate any of the following, and specially designed electronics, optics, and displays therefor: An infrared imaging camera core controlled in paragraph (c)(12)(i) through (xi) of this category;

ISSUE: The language in this proposal is very broad and appears to capture commercial thermography cameras, cameras for municipal fire firefighters, and personal vision systems (PVS) designed for outdoor enthusiasts. The Note to paragraph (c)(13) states that any of these devices specially designed to incorporate an IRFPA or IIT will be considered a Defense Article. This is in conflict with the language in (c)(13) where for example, a monocular incorporating a device controlled by (c)(12)(iii) [640x480 Microbolometer] would not be controlled under the ITAR. The following comments assume that the Note specifies the intent of this section.

1) Thermography cameras are specially designed for commercial and industrial applications. The language that states "including video-based articles having a separate near-to-eye display" could be interpreted to include any product with a near-to-eye display. It is common for commercial and industrial cameras to have near-to-eye displays for ease of use.
   a. FLUKE TiX1000 Thermography Camera. http://www.fluke.com/fluke/inen/thermal-cameras/fluke-tix1000.htm?pid=78909
   b. ICI IR640 P-Series http://www.infraredcamerasinc.com/ir-640-p.html
2) Firefighting Cameras. A few products currently exist for helmet mounted firefighting purposes. However, it is expected that in the near future that thermal cameras will be incorporated into firefighters breathing apparatuses and mounted or integrated into firefighter helmets.
   a. Sage Technologies Ltd helmet mounted camera for firefighters. http://gosage.com/HelmetVue.html
   b. Honeywell thermal camera mounting kit for firefighters. https://www.fishersci.com/shop/products/honeywell-fire-warrior-micro-thermal-imager/p-2661888
3) Commercial binoculars, biocculars, monoculars and helmet mounted articles incorporating IRFPAs will be captured by this language.
   a. Pulsar http://www.pulsarnv.com/pl77311.html
   b. FLIR Scout http://www.flir.com/hunting-outdoor/display/?id=44756
   c. FLIR BHS Handheld Thermal Camera (specially designed for consumer boaters and outdoor enthusiasts) http://www.flir.com/marine/display/?id=60445

4) Foreign availability. Products with near-to-eye displays are available from non-US sources and are controlled by the Wassenaar DUL. The proposed language will exclude US companies from selling abroad since non-US companies are selling dual-use items that would be captured by the

ITAR. Clearly, ITAR controlled products can't compete against similar performing dual-use products.

a. Jenoptik 1024 VarioCam http://www.jenoptik.com/en-variocam-hd-1024-research
b. NORIR – China. Cooled Dual-use binocular. http://www.norir.net/English/productsh.asp
c. Scout Guide (China) IR 517-35 640x480 UFPA monocular. http://www.flir-infrarotkameras.de/Scout-GUIDE-IR517-35640x480-4xZoom-Infraredcamera
d. Liemke M640 Wärmebildmonokular 640x480 monocular. http://www.lk-shop.com/neuheiten/106/liemke-m640-waermebildmonokular
e. Pyser-SGI Wärmebildmonokular PNP MTSD 640x480 monocular. http://www.lk-shop.com/neuheiten/109/pyser-sgi-waermebildmonokular-pnp-mtsd?c=80
f. Thermoteknix TiCam 750LR 640x480 UFPA biocular. http://www.scottcountry.co.uk/products_detail.asp?productID=5473

RECOMMENDATION: The language is broad and will capture dual-use products that are in normal commercial use and available from non-US sources. Additionally, the language is further confused by the Note to paragraph (c)(13) which is more restrictive than the language in this paragraph. It is recommended to specify military performance parameters or add the term "specially designed for military end-uses" to this section.

Note to paragraph (c)(13): The articles controlled in this paragraph include binoculars, bioculars, monoculars, goggles, or head- or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate an IRFPA or IIT article (e.g., IDCA, IRFPA assembly) and electronics separately.

ISSUE: This note adds greater restriction than the language in (c)(13), therefore adding confusion about what is intended for control.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards.

(c)(15) Infrared search and track (IRST) systems or equipment that incorporate or are specially designed to incorporate an article controlled in this category, and maintain positional or angular state of a target through time, and specially designed parts and components therefor;

ISSUE: There are no military parameters listed. This broad description will capture commercial and dual-use systems. For example,

1) commercial automobiles have night vision systems with algorithms to track and identify pedestrians. http://www.bing.com/images/search?q=bmw+night+vision+with+pedestrian+detection&qpvt=bmw+night+vision+with+pedestrian+detection&qpvt=bmw+night+vision+with+pedestrian+detection&FORM=IGRE
2) Commercial and industrial security cameras use video analytics which track specified targets. https://www.youtube.com/watch?v=2yqPs8vbGSg&feature=youtu.be&list=PL446FFA4A396BCC2C

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

> ***(c)(16)(i) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor: (i) Having two or more axes of active stabilization and a minimum rootmean-square (RMS) stabilization better (less) than 200 microradians;***

ISSUE: There are no military parameters listed. Commercial and industrial products may be captured.

RECOMMENDATION: Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

> ***(c)(16)(iii) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor: (iii) Fixed-site reconnaissance, surveillance or perimeter security systems or equipment having greater than 640 detector elements in any dimension;***

ISSUE: This paragraph captures products in normal commercial use and products that are available from non-US manufacturers. A new term is introduced which is not defined, and a new metric for detector elements is used which doesn't match parameters used previously in this document. Items belonging in section (e) "components" are improperly included in this section which is focused on end-item equipment.

1) Products commercially available from non-US manufacturers which have greater than 640 detector elements in any dimension. The products shown below are controlled on the Wassenaar DUL and not on the Wassenaar Munitions List.
    a. Selex Horizon HD Camera 1280x720 cooled IRFPA (dual-use rated) http://www.selex-es.com/documents/737448/13781372/body_mm07756_Horizon_MWIR_LQ_.pdf
    b. Cassidian Nightowl M-ER 1280x1024 cooled IRFPA. http://www.defenceandsecurity-airbusds.com/en_US/web/guest/z_nightowl_m_er
2) The term "fully packaged camera" is introduced in this paragraph and the definition is not provided. There is a definition of camera in the EAR. Note 1 to 6A003.b states: ***Imaging cameras described in 6A003.b.4 include "focal plane arrays" combined with sufficient "signal processing" electronics, beyond the read out integrated circuit, to enable as a minimum the output of an analog or digital signal once power is supplied.*** The EAR definition of Imaging Camera has been in place and implemented as a term understood by industry and confirmed through the State Department Commodity Jurisdiction (CJ) process. The Wassenaar DUL has also adopted the EAR definition for Imaging Camera.
3) The term "640 detector elements in any dimension" is used in this section. Other paragraphs specify the total number of pixels, e.g., (c)(12)(iii) uses 328,000 detector elements, and (c)(12)(vi) uses "greater than 256 elements." It's not clear if the term "328,000 detector elements" has the same meaning as "640 detector elements in any dimension."
4) Language including "***and specially designed electronics, optics, and displays"*** should be in section (e) components. Confusion is unnecessarily created by randomly inserting a few components in this section.

RECOMMENDTION: Fixed site security and surveillance systems are primarily dual-use in nature and available from non-US manufacturers. Specify a military performance parameter or add the term "specially designed for military end-uses" to this section. Either remove "fully packaged camera" or provide a definition that matches the EAR and Wassenaar definitions for camera. Lastly, utilize definitions related to detector element resolution in a consistent manner.

(c)(16)(vi) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor: (vi) Hardened to withstand electromagnetic pulse (EMP) or chemical, biological, or radiological threats;

ISSUE: It is possible that due to technological advancements those items could become able to withstand harsh threats listed in this section without specific design intent.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards.

(c)(18) Near-to-eye display systems or equipment, specially designed for articles controlled in this subchapter;

ISSUE: This more appropriately addressed in paragraph (e)(12) where components are addressed.

RECOMMENDATION: Remove this language from section and address the item in (e)(12).

Note 1 to paragraph (c): A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

ISSUE: The concept of a permanent encapsulated sensor assembly is 1) not well defined and 2) is not a bright line parameter to distinguish an ITAR item from a CCL item.

IRFPAs are packaged using various methods depending on the type of detector. Microbolometer IRFPAs/detectors are typically packaged in a sealed vacuum device. Photon detector IRFPAs may be packaged in different methods depending on many factors. A photon detector may eventually become packaged in a sealed vacuum assembly however; those steps have little to do with whether the device is military in nature. It's not clear why the "permanent encapsulated sensor assembly" is used as a military parameter. One can speculate that the USG is concerned about either reverse engineering of IRFPAs, diversion of IRFPAs, or both.

Permanent encapsulation will not eliminate reverse engineering by an entity that is knowledgeable, funded and motivated. However, reverse engineering is a concern for all technologies and companies such as FLIR institute extensive measures to protect intellectual property.

The motivation to purchase a camera assembly with the purpose to remove the IRFPA for diversion into a military system isn't practical. The availability of IRFPAs world-wide and the extra cost of purchasing a camera to harvest the IRFPA then dispose of the camera assembly isn't cost effective or practical on any type of a large scale basis. It is possible that there might be a one-off situation where an IRFPA is removed from a commercial camera, but it is unlikely to occur in volume.

In summary, FLIR is concerned that the encapsulation of an IRFPA is being used as a distinguishing parameter for a military item, which has no bearing on its military utility. Further, we are concerned that the definition of a permanent encapsulation sensor assembly is not sufficiently defined.

RECOMMENDATION: Remove this packaging concept as criteria for distinguishing a military item and add language that CAT XII will control FPAs specially designed for military applications.

> ***Note 2 to paragraph (c): The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), and (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable. Articles are not subject to the EAR until integrated into the item subject to the EAR. Defense articles intended to be integrated, and technical data and defense services directly related thereto remain subject to the ITAR prior to integration. See paragraph (f) of this category for enumerated technical data and software, and specific information subject to the EAR.***

ISSUE: This note represents multiple problems; A) a tamper protection concept is introduced with very little detail, B) Commercial practicalities of selling, operational training, manufacturing, logistics, and servicing, are not considered. Also, as explained throughout this document the CAT XII proposed language is attempting to place ITAR controls on dual-use items that are commercially available from non-US sources. This section would not be required if the CAT XII placed controls at the system level rather than the dual-use component level.

1) Tamper protection is a term that has been used as a concept by the USG related to dual-use products however, there has never been a clear definition. Based on discussions with the USG, the purpose of the proposed language is to make it impossible to remove a component from a commercial product so that it can't be diverted for military purposes.
    1. Most of the components of concern are available from non-US sources. It would not make sense to purchase an entire system to only harvest a component which is available commercially from sources outside of the US. It will be much more cost effective for an entity to purchase the components from a non-US manufacturer.
    2. Tamper protection introduces complications for sales to commercial customers. Customers are concerned that tamper measures may impact the reliability of the product. Additionally, it adds a level of complication to a product and potential "invasive" perception of a US product.
2) There are multiple commercial impracticalities associated with this proposed language for a non-US manufacturer integrating a US ITAR controlled item.
    1. State Department authorization will be required to provide the component to a non-US manufacturer of a dual-use item. This will most likely include a temporary export license (DSP-73), a hardware license (DSP-5), a temporary import license (DSP-61) and possibly a technical assistance agreement (TAA) to help the customer with integration.
        i. The ITAR does not allow a product to change jurisdiction outside of the US, so once the ITAR component is integrated into the dual-use product, the final

assembly must be returned to the US to gain dual-use jurisdiction. Upon this return to the US, an EAR authorization may be used for export of the product from the US to the intended destination. Clearly, this is a costly process that requires significant coordination and extensive knowledge of both the ITAR and the EAR. Due to these complications, this is not a path that most non-US manufacturers will be willing to take.

ii. Assuming the plan described in i. above, it will also be required that the non-US manufacturer incorporating this ITAR component be compliant with the ITAR. This involves control of access of ITAR data and hardware, communication of citizenship of non-US employees and many other ITAR requirements. Again, it is unlikely that a non-US manufacturer of a dual-use item will choose to take this ITAR intensive path.

2. It is cost-prohibitive to design a product where the critical components in the system will be permanently damaged when removed. Commercial markets are driving the growth of the thermal imaging requirements world-wide as shown in Figure 6. Commercial growth is contingent on lower costs and it isn't practical to have key components destroyed during routine maintenance, servicing or repair.
3. Many US manufacturers have service centers world-wide in order to perform maintenance, service and repair of its products. The proposed language will complicate the ability of US companies to service its products and thus negatively impact its ability to compete globally.
4. Many existing products would need to be redesigned in order to implement this proposed language. This would be an extreme hardship on US manufacturers who have already invested significant funds in product development. The result will be a loss of market share while redesigning products, and it will be a boon to non-US manufacturers who would not be under the same constraint to have components become inoperable when removed.

RECOMMENDATION: Remove this note in its entirety. It is so completely impractical in a commercial market place and would only result in greatly impeding US company's ability to compete in the global market.

(e) Parts, components, accessories, attachments, and associated equipment as follows:

ISSUE: This section is controlling items that are commercially available from non-US sources.

RECOMMENDATION**:** Specify a military performance parameter or add the term "specially designed for military end-uses" to this section.

(e)(3) Wafers incorporating structures for either a ROIC controlled in paragraph (e)(4) or (5) of this category, or an IRFPA or detector elements therefor controlled in paragraph (c)(2) of this category;

(e)(4) Read-Out Integrated Circuits (ROICs) specially designed for an IRFPA controlled in paragraph (c)(2) of this category or detector elements therefor, as follows:

Note to paragraph (e)(4): ROICs are specially designed for an infrared focal plane array detector even if the detector is incorporated into an item that is not enumerated on the U.S. Munitions List.

(e)(5) ROICs specially designed for a camera/core/packaged IRFPA subject to the controls of this subchapter;

ISSUE: (e)(3), (e)(4), Note to (e)(4) and (e)(5) will be addressed together. The details for the design and manufacturing of ROICs for IRFPAs are widely available in the public domain. There are hundreds of patents issued and annual papers published and presented at international technical symposiums. ROIC design techniques are taught in universities and at conferences. Entities located outside of the US and Wassenaar, such as China, Taiwan, and Israel design and manufacture ROICs for infrared focal plane arrays. The ROIC devices are manufactured at silicon foundries world-wide. Existence of this technical capability outside of the US and Wassenaar is evident by the significant number of patents and published papers available on this technology.

1) Patents. A search of the United States Patent Technology Office database produced over five hundred (500) patents issued worldwide directly related to ROICs for IRFPAs and are listed in Exhibit A. Additionally, of the five hundred patents there are over fifty (50) patents issued to entities in China, listed in Exhibit B. The patent searches performed for these reports were not exhaustive and it is highly likely that many more patents related to this technology would be found after a more thorough search.
2) Published Papers. Papers have been published for decades on the details of the design and testing of ROICs. Following are a few examples of papers that have been published by entities outside of Wassenaar on this topic.
    a. The Institution of Electronics and Telecommunications Engineers (IETE) Journal of Research has published many relevant papers including: "320x256 Readout Integrated Circuit for Infrared Focal Plane Arrays with Low-Temperature MOSFET Model." Authored by a team from the National ASIC System Engineering Research Center, Southeast University, Nanjing, Jiangsu, China.
    b. SPIE – "Optimization of Readout Circuit with Background Suppression for Dual-Band Quantum Well Infrared Focal Plane Array Photodetector." Authored by a team from the National Chi Nan University in Taiwan.
    c. SPIE Photonics Asia – "Design low-noise readout circuit for near-infrared InGaAs focal plane array", Paper 8562-4 Author(s): Zhangcheng Huang, Huang Songlei, Jiaxiong Fang, Shanghai Institute of Technical Physics (China)
3) Conferences / Symposiums. The International Society of Optical Engineering (SPIE) hosts symposiums where papers on details related to ROICs, focal plane arrays, lasers, and many other electro-optical devices are presented. Additionally, SPIE offers classes related to ROIC design at conferences, such as the Defense, Security and Sensing (DSS) Symposium, in Baltimore. The following examples represent just a small sampling of the over one hundred courses offered either on-line or during a given DSS Symposium as well as courses that have been offered for over twenty years.
    a. Analog-to-Digital Converters for Digital ROICs (SC1076). This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors.
    b. The SPIE database contains charts and notes from ROIC and FPA design courses taught annually going back to 1994.

   c. The presentations and courses presented at SPIE are typically approved by the US DOD, and are attended by international and domestic audiences.

4) University Degrees. Many US and non-US universities have practical courses in IC design. Some of the best universities in this area of study are MIT, Stanford, UC Berkeley, Cal Tech, and the University of Utah. It is common for non-US citizens, including Chinese nationals, who have been educated and received advanced degrees from one of the universities listed above, to apply for and in some cases be hired for IC design positions to US companies that design ROICs.
5) Consequences. In addition to the basic issue that the technology is widely available, the proposed control will only serve to hamstring US manufacturers of ROICs and IRFPAs. There are consumer level products such as CCD video cameras, automotive sensors, and gaming sensors (X-Box) that will be burdened with new export controls. Currently, the automotive and gaming industries use NIR monolithic FPAs with non-eye-safe lasers. Measuring ranges is required for these industries and the need for longer ranges and increased pixel counts is growing. Because of FDA safety requirements this need is driving laser wavelengths into the eye-safe SWIR band and consequently these industries will be profoundly impacted by this proposed control on ROICs. The proposed language casts an overly broad net that will capture not only existing consumer products but also those that are under development or not yet envisioned.
6) Non-US sources provide ROICs on a commercial basis.
   a. Mikro Tasarim, in Turkey is a merchant supplier of ROICs for IRFPAs offer a variety of ROICs including a 1280x1024 for SWIR IRFPAs. http://www.mikro-tasarim.com.tr/products
   b. Xenics, in Belgium offers a wide variety of IRFPA devices and ROIC design services. http://www.xenics.com/en/application/custom-infrared-roic-design
   c. New Imaging Techologies (NIT), in France offers standard components and ROIC design services. http://www.new-imaging-technologies.com/ingaas-products.html
   d. Tumsis, in Turkey designs ROICs for IRFPAs. http://www.tumsis.com/capabilities.html
   e. Imec, in Belgium offers components and design services. http://www2.imec.be/be_en/research/image-sensors-and-vision-systems/hyperspectral-imaging.html
7) Major non-US IRFPA manufacturers have in-house ROIC design capability. Companies such as Semi-Conductor Devices (SCD) in Israel, Sagem and Sofradir in France, Selex in the UK all have in-house ROIC design capability.
8) As shown in Figure 2 there are many Chinese IRFPA manufacturers and they claim to design their own ROICs for the IRFPAs they manufacture. The ROICs are manufactured at silicon foundries in China.
9) As noted by BIS in the CAT XII Website Guidance dated 15 June 2015, many ROICs for IRFPAs not designed for military applications have been controlled as EAR 99 dual-use items.

RECOMMENDATION: ROIC design capability and commercially available devices are available world-wide, and ROICs are manufactured world-wide. Placing broad controls on these devices will have a negative impact on US companies who design these devices, to commercial silicon foundries which manufacture ROICs, and also to customers for ROICs. Non-US ROIC designers will flourish and their intellectual property portfolios will continue to expand. It is not possible to identify specific parameters that are unique to a military end-use for ROICs. As a result the only solution is to incorporate the term "specially designed for military end-uses" to this section.

(e(6) Vacuum packages or other sealed enclosures for an IRFPA or IIT controlled in paragraph (c) of this category specially designed for

incorporation or integration into an article controlled in paragraphs (a), (b), or (c) of this category;

ISSUE: As detailed in section (c) there are a large number of non-US companies which design, manufacture and sell IRFPAs and products incorporating IRFPAs. IRFPAs typically are installed in vacuum packages and other sealed enclosures. IRFPA manufacturers typically have this packaging capability in-house. Given the wide spread availability of IRFPAs and packaging capability it is not logical to place ITAR controls on US companies for this technology.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards. During the CAT XV review it was agreed that designing and building to military standards must be intentional and it was acknowledged that these requirements are significant cost drivers.

(e)(7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components, as follows:
(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

ISSUE: Cryocooler technology is not unique to the US. The technology is available world-wide and there are technical groups, such as the Cryogenic Society of America http://www.cryogenicsociety.org/ which welcome an international roster of members. The CSA website has significant technical data and resources related to cryocoolers. The parameters listed in this section are outdated and don't represent military specifications. Typical commercially available cryocoolers have a MTTF of 10,000 to 30,000 hours.

Non-US availability
1) Ricor in Israel has a vast array of cryocoolers commercially available. http://www.ricor.com/products/comparison-table/
2) Aim in Germany has a vast array of cryocoolers commercially available. http://www.aim-ir.com/en/main/products/cryocoolers.html
3) Thales in France has a vast array of cryocoolers commercially available. http://www.thales-cryogenics.com/

RECOMMENDATION: Cryocoolers are not unique to the US and the standard performance is well beyond the requirement listed in this section. This CAT XII document must specify a military performance parameter or add the term "specially designed for military end-uses" to this section. Additionally, the approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards. During the CAT XV review it was agreed that designing and building to military standards must be intentional and it was acknowledged that these requirements are significant cost drivers.

(e)(7) (ii) Active cold fingers;

ISSUE: All IDCAs have active cold fingers.

RECOMMENDATION: Remove from the ITAR unless specially designed for military end-uses.

(e)(7)(iv) Dewars specially designed for articles controlled in paragraphs (a), (b) or (c) of this category;

ISSUE: There are no military parameters or use restrictions listed. As demonstrated in this document, not all of the articles currently listed in the draft proposal are military items. Additionally, there should be a definition that distinguishes the items covered in this section and the vacuum packages covered in (e)(6).

RECOMMENDATION: Remove from the ITAR unless specially designed for military end-uses. Additionally, the approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards. During the CAT XV review it was agreed that designing and building to military standards must be intentional and it was acknowledged that these requirements are significant cost drivers.

(e)(9) Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category;

ISSUE: There are no military parameters or use restrictions listed. As detailed in section (c) there are a large number of non-US companies which design, manufacture and sell products which are proposed for control in CAT XII. Given the world-wide availability of products covered in CAT XII it is not logical to place ITAR controls on US companies for this technology.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards.

(e)(10) Drive, control, signal or image processing electronics, specially designed for articles controlled in this category;

ISSUE: There are no military parameters or use restrictions listed. As detailed in section (c) there are a large number of non-US companies which design, manufacture and sell products which are proposed for control in CAT XII. Given the world-wide availability of products covered in CAT XII it is not logical to place ITAR controls on US companies for this technology.

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards. During the CAT XV review it was agreed that designing and building to military standards must be intentional and it was acknowledged that these requirements are significant cost drivers.

(e)(12) Near-to-eye displays specially designed for articles controlled in this category;

ISSUE: There are no military parameters or use restrictions listed. As detailed in section (c) there are a large number of non-US companies which design, manufacture and sell products which are proposed for control in CAT XII. Given the world-wide availability of products covered in CAT XII it is not logical to place ITAR controls on US companies for this technology.

Commercially Available. The companies below manufacture near to eye displays that are used in consumer level products, such as Google Glasses, and also for military thermal weapon sights.

1) Kopin Corporation. http://www.kopin.com/capabilities/display
2) eMagin. http://www.emagin.com/oled-microdisplays/

Non-US Sources

1) ECVV, China. http://www.ecvv.com/product/3230547.html
2) Holoeyes Photonics, Germany. http://holoeye.com/lcos-microdisplays/
3) The Micro Display page. This is a European maintained reference to research and manufacturers of micro displays http://tfcg.elis.ugent.be/microdis/

RECOMMENDATION: The approach taken in Category XV is a logical approach. Products must be designed, rated, tested or advertised to be considered military. The military does not purchase products without validation and certification of environmental design and implementation standards.

Note to paragraph (e): The articles described in this paragraph are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable. Articles are not subject to the EAR until integrated into the item subject to the EAR. Defense articles intended to be integrated, and technical data and defense services directly related thereto, remain subject to the ITAR prior to integration. See paragraph (f) of this category for enumerated technical data and software, and specific information subject to the EAR.

ISSUE: There are multiple commercial impracticalities associated with this proposed language for a non-US manufacturer integrating a US ITAR controlled item.

1. State Department authorization will be required to provide the component to a non-US manufacturer of a dual-use item. This will most likely include a temporary export license (DSP-73), a hardware license (DSP-5), a temporary import license (DSP-61) and possibly a technical assistance agreement (TAA) to help the customer with integration.
   i. The ITAR does not allow a product to change jurisdiction outside of the US, so once the ITAR component is integrated into the dual-use product, the final assembly must be returned to the US to gain dual-use jurisdiction. Upon return to the US, an EAR authorization may be used for export of the product from the US to the intended destination. Clearly, this is a costly process that requires significant coordination and extensive knowledge of both the ITAR and the EAR. This is not a path that a non-US manufacturer is likely to take.
   ii. Assuming the plan described in i. above, it will also be required that the non-US manufacturer incorporating this ITAR component be compliant with the ITAR. This involves control of access of ITAR data and hardware, communication of

citizenship of non-US employees and many other ITAR requirements. It is unlikely that a non-US manufacturer of a dual-use item will choose to take this ITAR intensive path.

2. It is cost-prohibitive to design a product where the critical components in the system will be permanently damaged when removed. Commercial markets are driving the growth of the thermal imaging requirements world-wide as shown in Figure 6. Commercial growth is contingent on lower costs and it isn't practical to have key components destroyed during routine maintenance, servicing or repair.
3. Many US manufacturers have service centers world-wide in order to perform maintenance, service and repair of its products. The proposed language will complicate the ability of US companies to service its products and thus negatively impact its ability to compete globally.
4. Many existing products would need to be re-designed in order to implement this proposed language. This would be an extreme hardship on US manufacturers who have already invested significant funds in product development. The result will be a loss of market share while re-designing products, and it will be a boon to non-US manufacturers who would not be under the same constraint to have components become inoperable when removed.

RECOMMENDATION: Remove this note in its entirety. It is so completely impractical in a commercial market place and would only result in greatly impeding US company's ability to compete in the global market.

(f) Technical data (as defined in §120.10 of this subchapter) and defense services (as defined in §120.9 of this subchapter) directly related to the defense articles enumerated in paragraphs (a) through (e) of this category. (See §125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)

ISSUE: It is difficult to comment on this section since the articles proposed for control in CAT XII are primarily dual-use items as detailed in this paper. Additionally, this section needs further review considering that DDTC and BIS have just released for public comment proposed definitions related to technical data.

RECOMMENDATION: This section (f) requires revision once CAT XII is drafted to properly address only military items, and also requires close coordination with the BIS and DDTC proposed definitions for technical data and software.

CONCLUSION

FLIR is greatly concerned that the proposal for Category XII does not reflect the expressed purpose of ECR. The proposed draft for CAT XII fails for several reasons as listed below.

- Commercial markets dominate sales of many technologies described in the Category XII draft
- Foreign availability is not adequately considered
- Actual military items are not specified in the proposal

It is incredibly disappointing that the result of multiple years of review of Category XII by the USG Interagency group resulted in a proposal that has serious negative consequences to US industry.

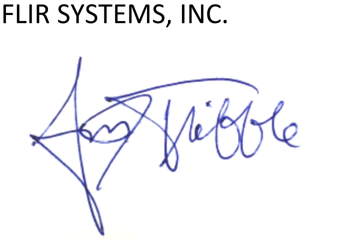
- US companies will be restricted from competing globally
- Non-US sales for commercial and dual-use applications for thermal imaging represent half of the world-wide demand for this technology[4]. US companies will not be able to access these critical revenue sources.
- Advanced technology development will be impeded by reduced financial resources that would be available from non-US sales. Non-US sales have been essential to fund R&D especially since US DOD funding for IRFPA technology development has been greatly reduced over the past decade.
- US companies will not be incentivized to continue to invest in US based technology or factories
- Non-US companies will be motivated to continue to invest in developing this technology and will ultimately dominate the market

Placing ITAR controls on dual-use technology will have the unintended effect of strengthening non-US companies at the expense of US manufacturers. Overseas customers will avoid ITAR controls by turning to those offshore producers; US producers will lose economies of scale, and in the end America's military will become dependent on non-US sources for this vital technology.

Therefore, FLIR recommends that this proposal be fundamentally rewritten after thorough and sincere collaboration with stakeholders among industry, USG, and research institutes. FLIR has been an active participant in this CAT XII discussion by participation and assuming leadership roles in Industry / Government organizations such as the Department of Commerce's Sensors and Instrumentation Technical Advisory Committee (SITAC), and the State Department's Defense Trade Advisory Group (DTAG). FLIR is committed to continue to partner with the USG and work towards the creation of a meaningful and logical path forward to assure protection of US national security as well as create an environment that will allow US companies to thrive, innovate, create jobs, compete globally, and support maintaining US leadership in a critical technology.

Please contact the undersigned by phone at 503-498-3301 or email at steve.tribble@flir.com

Best regards,
FLIR SYSTEMS, INC.



Steven J. Tribble
Vice President, Global Trade Compliance

[4] MaxTech International 2015 Report "The World Market for Commercial and Dual-Use Infrared Imaging and Infrared Thermometry Equipment"

ROIC and Infrared Focal Plane Array Patents

as of 3 January 2013

(this is not an exhaustive list, it is a sampling)

Item No.	Publication No.	Country	Source	Title	Application No.	Assignee
1	CN102095501	CN	CN Patents	Irfpa (infrared focal plane array) and read-out circuit thereof	CN201010570406	Beijing Guangwei Integrated Circuit Inc.
2	CN102095501	CN	CN Patents	Irfpa (infrared focal plane array) and read-out circuit thereof	CN201010570406	Beijing Guangwei Integrated Circuit Inc.
3	US5326996	US	US Grants	Charge skimming and variable integration time in focal plane arrays	US08/087034	Bae Systems Information And Electronic Systems Integration Inc.
4	US7180046	US	US Grants	Focal plane array with on-chip low-voltage differential serial interface	US10/903565	Bae Systems Information And Electronic Systems Integration Inc.
5	US20060022119	US	US Applications	Focal plane array with on-chip low-voltage differential serial interface	US10/903565	Bae Systems Information And Electronic Systems Integration Inc.
6	US6028309	US	US Grants	Methods and circuitry for correcting temperature-induced errors in microbolometer focal plane array	US09/021714	Flir Systems, Inc.
7	US6675600	US	US Grants	Thermal mismatch compensation technique for integrated circuit assemblies	US10/310230	Schilmass Co. L.l.c.
8	WO9715813	WO	WO Applications	Uncooled focal plane array sensor	US96170	Lockheed-martin Ir Imaging Systems, Inc.
9	CN102447845	CN	CN Patents	Infrared focal plane array readout circuit and adaptive power consumption regulation method thereof	CN201110299627	Peking University
10	WO2005008197	WO	WO Applications	Dual-mode focal plane array for missile seekers	US03404	Bae Systems Information And Electronic Systems Integration Inc.
11	US20100118168	US	US Applications	High density composite focal plane array	US12/327383	Bae Systems Information And Electronic Systems Integration Inc.
12	US5512748	US	US Grants	Thermal imaging system with a monolithic focal plane array and method	US08/281711	L-3 Communications Corporation
13	US7132648	US	US Grants	Uniform, non-disruptive, and radiometrically accurate calibration of infrared focal plane arrays using global sc	US10/824285	Science & Technology Corporation @ Unm
14	US5743006	US	US Grants	Method for fabricating a focal plane array for thermal imaging system	US08/485957	L-3 Communications Corporation
15	US5789736	US	US Grants	Signal readout circuit having a two-dimensional focal plane cell array capable of reading out signals with impr	US08/690943	Nec Corporation
16	US6498346	US	US Grants	Large dynamic range focal plane array	US09/666296	Lockheed Martin Corporation
17	US5227656	US	US Grants	Electro-optical detector array	US07/609678	L-3 Communications Corporation
18	US7135680	US	US Grants	Focal plane processor for ir detection	US10/511000	Semi Conductor Devices (scd) Partnership
19	CN101304003	CN	CN Patents	Single slice integration technique for diffraction microlens array and ultraviolet focal plane array	CN200710040514	University Of Shanghai For Science And Technology
20	CN101304003	CN	CN Patents	Single slice integration technique for diffraction microlens array and ultraviolet focal plane array	CN200710040514	University Of Shanghai For Science And Technology
21	CN2754070	CN	CN Patents	Background current inhibition reading-out circuit for infrared focal plane array	CN200420061801	Chongqing Univ.
22	US5449907	US	US Grants	Programmable on-focal plane signal processor	US08/142996	International Business Machines Corp.
23	US5644838	US	US Grants	Method of fabricating a focal plane array for hybrid thermal imaging system	US08/368066	L-3 Communications Corporation
24	US6791610	US	US Grants	Uncooled focal plane array sensor	US09/051180	Lockheed-martin Ir Imaging Systems, Inc.
25	WO2004053443	WO	WO Applications	Thermal mismatch compensation technique for integrated circuit assemblies	US02389	Bae Systems Information And Electronic Systems Integration Inc
26	US6031231	US	US Grants	Infrared focal plane array	US08/927407	Mitsubishi Denki Kabushiki Kaisha
27	US5610389	US	US Grants	Stabilized hybrid focal plane array structure	US08/409229	Drs Sensors & Targeting Systems, Inc.
28	US5604977	US	US Grants	Method of fabricating focal plane array	US08/478570	L-3 Communications Corporation
29	US6906326	US	US Grants	Quantum dot infrared photodetector focal plane array	US10/627460	Retro Reflective Optics, Llc
30	US5585624	US	US Grants	Apparatus and method for mounting and stabilizing a hybrid focal plane array	US08/409230	Drs Sensors & Targeting Systems, Inc.
31	CN101246047	CN	CN Patents	Infrared focal plane array dark field current compensation circuit and method thereof	CN200710049358	University Of Electronic Science And Technology Of China
32	US7566942	US	US Grants	Multi-spectral pixel and focal plane array	US11/251955	Massachusetts Institute Of Technology
33	CN100587419	CN	CN Patents	Infrared focal plane array dark field current compensation circuit	CN200710049358	University Of Electronic Science And Technology Of China
34	CN101635295	CN	CN Patents	Quantum well infrared focal plane array and manufacturing method	CN200910041873	Sun Yat-sen University
35	KR101153722	KR	KR Patents	System in package method of semi-active focal plansystem in package method of semi-active focal plane arra	KR20110023039	Korea Advanced Institute Of Science And Technology
36	CN102494784	CN	CN Patents	Readout circuit and readout method for point-by-point bias correction data of infrared focal plane array imag	CN201110419260	University Of Electronic Science And Technology Of China
37	US20020166968	US	US Applications	Apparatus and method of measuring bolometric resistance changes in an uncooled and thermally unstabilize	US09/853245	Irvine Sensors Corporation
38	CN102564599	CN	CN Patents	Readout circuit in infrared focal plane array and reference resistor of readout circuit as well as manufacturing	CN201110437202	University Of Electronic Science And Technology Of China
39	CN101635295	CN	CN Patents	Quantum well infrared focal plane array and manufacturing method	CN200910041873	Sun Yat-sen University
40	CN102589718	CN	CN Patents	Reading method of silicon substrate focal plane device	CN201210045860	Zhang Kang
41	CN102589719	CN	CN Patents	Reading circuit of silicon substrate focal plane device	CN201210045862	Zhang Kang
42	US7491938	US	US Grants	Multi-spectral uncooled microbolometer detectors	US11/589525	Bae Systems Information And Electronic Systems Integration Inc.
43	WO2006044983	WO	WO Applications	Multi-spectral pixel and focal plane array	US20050376	Massachusetts Institute Of Technology
44	US5486698	US	US Grants	Thermal imaging system with integrated thermal chopper	US08/229497	L-3 Communications Corporation
45	US6249002	US	US Grants	Bolometric focal plane array	US09/011942	Lockheed-martin Ir Imaging Systems, Inc.
46	US4956695	US	US Grants	Three-dimensional packaging of focal plane assemblies using ceramic spacers	US07/351122	Rockwell International Corporation
47	US6005266	US	US Grants	Very low leakage jfet for monolithically integrated arrays	US08/816313	Princeton University, The Trustees Of
48	US20050017176	US	US Applications	Quantum dot infrared photodetector focal plane array	US10/627460	Retro Reflective Optics, Llc
49	US6495830	US	US Grants	Programmable hyper-spectral infrared focal plane arrays	US09/666828	Lockheed Martin Corporation
50	US5523570	US	US Grants	Double direct injection dual band sensor readout input circuit	US08/276037	Bae Systems Information And Electronic Systems Integration Inc.
51	US5875113	US	US Grants	Process to prevent the exploitation of illicit knowledge of the structure or function of an integrated circuit	US08/746307	Cordell; Steve
52	US20090173883	US	US Applications	Multi-band focal plane array	US11/493121	Northrop Grumman Systems Corporation
53	US7592593	US	US Grants	Multi-band focal plane array	US11/493121	Northrop Grumman Systems Corporation
54	CN102214662	CN	CN Patents	Monolithic integration structure of un-cooled infrared focal plane array detector and manufacturing method	CN201110105424	Peking University
55	JP10281869	JP	JP Applications	Low crosstalk row differential circuit architecture for integrated dichroic focal plane array	JP351565	He Holdings Inc Dba Hughes Electron
56	US20080179520	US	US Applications	Direct-view focal plane array	US11/699839	Northrop Grumman Corporation
57	CN1165078	CN	CN Patents	Pixel array layout method and metal wire structure for focal plane read-out circuit	CN01134707	Beijing University
58	EP1837911	EP	EP Applications	Infrared focal plane array	EP07110375	Mitsubishi Denki Kabushiki Kaisha
59	CN102280456	CN	CN Patents	An infrared focal plane array probe integrated structure and preparation method	CN201110121051	Peking University
60	JP8313359	JP	JP Applications	Focal plane array for hybrid thermal imaging device and manufacture thereof	JP113	Texas Instr Inc Lt;tigt;
61	EP0721224	EP	EP Applications	Focal plane array for hybrid thermal imaging system and method	EP953095	Raytheon Company
62	CN1348209	CN	CN Patents	Pixel array layout method and metal wire structure for focal plane read-out circuit	CN01134707	Beijing Univ.

63	US20070176104	US	US Applications	Multi-spectral uncooled microbolometer detectors	US11/589525	Bae Systems Information And Electronic Systems Integration Inc.
64	JP3187760	JP	JP Grants	Low crosstalk row differential circuit architecture for integrated dichroic focal plane array	JP351565	He Holdings Inc Dba Hughes Electron
65	US20060118729	US	US Applications	Multicycle integration focal plane array (mifpa) for lock-in (li-), gated (g-), and gated lock-in (gli-) imaging, spe	US10/002861	
66	US5424544	US	US Grants	Inter-pixel thermal isolation for hybrid thermal detectors	US08/235835	L-3 Communications Corporation
67	US20120138774	US	US Applications	Focal plane array processing method and apparatus	US13/299995	The Massachusetts Institute Of Technology
68	US7105371	US	US Grants	Method of acquiring an image from an optical structure having pixels with dedicated readout circuits	US10/712844	California Institute Of Technology
69	CN202120912	CN	CN Patents	Non-refrigeration infrared focal plane array detector	CN201120147997	Ir Co Ltd Wuhan High German
70	US5128534	US	US Grants	High charge capacity focal plane array readout cell	US07/554238	Microelectronics Technology, Inc.
71	EP0849802	EP	EP Grants	Low-crosstalk differencing circuit architecture for integrated two-color focal plane arrays	EP973101	Raytheon Company
72	US20090250612	US	US Applications	Post-supported microbolometer pixel	US12/303125	Bae Systems Information And Electronic Systems Integration Inc.
73	US5426303	US	US Grants	Thermal isolation structure for hybrid thermal detectors	US08/235068	L-3 Communications Corporation
74	CN101995295	CN	CN Patents	Non-refrigerating infrared focal plane array as well as preparation method and application thereof	CN200910090545	Peking University
75	US5478242	US	US Grants	Thermal isolation of hybrid thermal detectors through an anisotropic etch	US08/236778	L-3 Communications Corporation
76	US5532484	US	US Grants	Defective pixel signal substitution in thermal imaging systems	US08/304001	L-3 Communications Corporation
77	WO9835212	WO	WO Applications	Methods and circuitry for correcting temperature-induced errors in microbolometer focal plane array	US98020	Indigo Systems Corporation
78	US5663564	US	US Grants	Photovoltaic detector with integrated dark current offset correction	US08/618699	Santa Barbara Research Center
79	EP2363887	EP	EP Applications	Focal plane array and method for manufacturing the same	EP10155249	Sensonor Technologies As
80	EP2363888	EP	EP Applications	Focal plane array and method for manufacturing the same	EP10155250	Sensonor Technologies As
81	US5410145	US	US Grants	Light detector using reverse biased photodiodes with dark current compensation	US08/202127	Coroy, Trenton G.
82	US20030122077	US	US Applications	Method and apparatus for temperature compensation of an uncooled focal plane array	US10/281393	Aprolase Development Co., Llc
83	US20020166967	US	US Applications	Method and apparatus for temperature compensation of an uncooled focal plane array	US09/853819	Aprolase Development Co., Llc
84	EP0651566	EP	EP Applications	Programmable on-focal plane signal processor.	EP94115178	International Business Machines Corporation
85	US5602043	US	US Grants	Monolithic thermal detector with pyroelectric film and method	US08/368067	Texas Instruments Incorporated
86	US20110315880	US	US Applications	Teramos-terahertz thermal sensor and focal plane array	US13/141694	
87	CN102280455	CN	CN Patents	Non-a is made the cooled infrared focal plane array probe	CN201110120925	Ir Co Ltd Wuhan High German
88	US8320423	US	US Grants	Compact, all solid-state, avalanche photodiode emitter-detector pixel with electronically selectable, passive o	US12/806904	
89	CN101825516	CN	CN Patents	Device and method for testing infrared focal plane array device	CN201010161721	University Of Electronic Science And Technology Of China
90	US6891160	US	US Grants	Method and apparatus for temperature compensation of an uncooled focal plane array	US10/281393	Aprolase Development Co., Llc
91	US6555842	US	US Grants	Active pixel sensor with intra-pixel charge transfer	US09/604846	California Institute Of Technology
92	US6476392	US	US Grants	Method and apparatus for temperature compensation of an uncooled focal plane array	US09/853819	Aprolase Development Co., Llc
93	US4369458	US	US Grants	Self-aligned, flip-chip focal plane array configuration	US06/165158	Micron Technology, Inc.
94	US5382977	US	US Grants	Electronically scanned buffered direct injection circuit for staring ir focal plane array	US08/124845	Rockwell International Corporation
95	JP2012531070	JP	JP Patents	Miniature phase revision antenna for high resolution focal plane thz image pickup array	JP2012513283	Ohio State Di Salt Lake City
96	US20070034776	US	US Applications	Active search sensor and a method of detection using non-specular reflections	US11/064589	Bae Systems Information And Electronic Systems Integration Inc.
97	EP0859413	EP	EP Applications	Infrared focal plane array	EP98100324	Mitsubishi Denki Kabushiki Kaisha
98	US5847390	US	US Grants	Reduced stress electrode for focal plane array of thermal imaging system and method	US08/838663	Raytheon Company
99	US8294099	US	US Grants	On-wafer butted microbolometer imaging array	US12/757247	Bae Systems Information And Electronic Systems Integration Inc.
100	CN102384789	CN	CN Patents	Infrared focal plane array device and manufacture method thereof	CN201010267982	Institute Of Microelectronics Chinese Academy Of Sciences
101	US5757000	US	US Grants	Reduced stress focal plane array for thermal imaging system and method	US08/842933	Raytheon Company
102	EP0507541	EP	EP Applications	Infrared focal plane array processor with integrator and low pass filter per pixel.	EP92302814	Raytheon Company
103	EP1463960	EP	EP Applications	Dual mode adaptive threshold architecture for 3-d ladar focal plane array	EP037012	Raytheon Company
104	US20060091284	US	US Applications	Multi-spectral pixel and focal plane array	US11/251955	Massachusetts Institute Of Technology
105	US5834775	US	US Grants	Integral slot shield for infrared focal plane arrays	US08/768254	Drs Infrared Technologies, Lp
106	EP0553406	EP	EP Applications	Readout amplifier for staring ir focal plane array.	EP921188	Rockwell International Corporation
107	US20100258725	US	US Applications	On-wafer butted microbolometer imaging array	US12/757247	Bae Systems Information And Electronic Systems Integration, Inc.
108	US5751005	US	US Grants	Low-crosstalk column differencing circuit architecture for integrated two-color focal plane arrays	US08/770311	Raytheon Company
109	EP0678756	EP	EP Grants	Staring focal plane array architecture for multiple applications	EP951058	Raytheon Ti Systems, Inc.
110	US20080079704	US	US Applications	Multi-color read-out integrated circuit	US11/529811	Teledyne Scientific & Imaging, Llc
111	US5756999	US	US Grants	Methods and circuitry for correcting temperature-induced errors in microbolometer focal plane array	US08/799663	Flir Systems, Inc.
112	US5268576	US	US Grants	Infrared focal plane array processor with integration and low pass filter per pixel	US07/942113	Raytheon Company, A Corporation Of Delaware
113	US5574282	US	US Grants	Thermal isolation for hybrid thermal detectors	US08/268365	Texas Instruments Incorporated, A Corp. Of Delaware
114	US6359290	US	US Grants	Self-aligned bump bond infrared focal plane array architecture	US08/595901	Raytheon Company
115	US20040011962	US	US Applications	Multicycle integration focal plane array (mifpa) for lock-in (li-), gated (g-), and gated lock-in (gli-) imaging, spe	US10/973710	Chin Ken K.
116	US5578826	US	US Grants	Thermal isolation for hybrid thermal detectors	US08/468159	Texas Instruments Incorporated, A Corp. Of Delaware
117	US5846850	US	US Grants	Double sided interdiffusion process and structure for a double layer heterojunction focal plane array	US08/706583	Drs Infrared Technologies, Lp
118	US7489351	US	US Grants	Dynamic range extension for focal plane arrays	US11/038167	Schilmass Co. L.l.c.
119	US6649913	US	US Grants	Method and apparatus providing focal plane array active thermal control elements	US10/084687	Raytheon Company
120	US6384413	US	US Grants	Focal plane infrared readout circuit	US09/416964	California Institute Of Technology
121	US5536680	US	US Grants	Self-aligned bump bond infrared focal plane array architecture	US08/437614	Texas Instruments Incorporated
122	US20060164530	US	US Applications	Dynamic range extension for focal plane arrays	US11/038167	Schilmass Co. L.l.c.
123	US5327234	US	US Grants	Time delay and integrate focal plane array detector	US07/729659	Raytheon Company, A Corporation Of Delaware
124	US20060125940	US	US Applications	Substitution of defective readout circuits in imagers	US10/011841	Bae Systems Information And Electronic Systems Integration Inc.
125	WO2006023160	WO	WO Applications	Focal plane array with on-chip low-voltage differential serial interface	US20050248	Bae Systems Information And Electronic Systems Integration Inc.
126	US20050279920	US	US Applications	Self-pixelating focal plane array with electronic output	US10/873045	The Boeing Company
127	US6479320	US	US Grants	Vacuum package fabrication of microelectromechanical system devices with integrated circuit components	US09/496826	L-3 Communications Corporation

128	US6586831	US	US Grants	Vacuum package fabrication of integrated circuit components	US09/928031	L-3 Communications Corporation
129	USRE40249	US	US Grants	Infrared imaging system employing on-focal plane nonuniformity correction	US09/667826	Amber Engineering, Inc., California
130	CN101242495	CN	CN Patents	Self-adapted digitalization method and its circuit for infrared plane array	CN200710020008	Nanjing University Of Science And Technology
131	US20100044552	US	US Applications	Automatic simultaneous dual gain readout integrated circuit using threshold voltage shifts of mosfet bulk to s	US12/194505	Lockheed Martin Corporation
132	WO2010021894	WO	WO Applications	Automatic simultaneous dual gain readout integrated circuit using threshold voltage shifts of mosfeet bulk to	US20090536	Lockheed Martin Corporation
133	CN100544411	CN	CN Patents	Self-adapted digitalization method and its circuit for infrared plane array	CN200710020008	Nanjing University Of Science And Technology
134	WO03103364	WO	WO Applications	Focal plane processor for ir detection	IL03004	Semi Conductor Devices (scd) Partnership
135	US5113365	US	US Grants	Method and charge coupled apparatus for algorithmic computations	US07/352765	Massachusetts Institute Of Technology, A Corp. Of Massachusetts
136	US7269359	US	US Grants	Focal plane array with synchronous detection circuits for an active remote sensing system	US10/322692	Exelis Inc.
137	US8319862	US	US Grants	Non-uniformity correction of images generated by focal plane arrays of photodetectors	US12/162366	Rafael Advanced Defense Systems Ltd.
138	US20050072923	US	US Applications	Focal plane processor for ir detection	US10/442934	Semi Conductor Devices (scd) Partnership
139	US20120248288	US	US Applications	Dual well read-out integrated circuit (roic)	US13/074290	Flir Systems, Inc.
140	WO9708753	WO	WO Applications	Bolometric focal plane array	US96138	Lockheed-martin Ir Imaging Systems
141	US5811808	US	US Grants	Infrared imaging system employing on-focal plane nonuniformity correction	US08/712891	Amber Engineering, Inc., California
142	US5296816	US	US Grants	Integrated circuit sensor and detector and spectrometers incorporating the sensor	US07/820862	Micromass Uk Limited
143	EP0645925	EP	EP Grants	A signal readout circuit and its drive circuit	EP94114560	Nec Corporation
144	US6204496	US	US Grants	Focal plane readout unit cell induced pulse diversion circuit and method	US09/163930	Raytheon Company
145	US4660066	US	US Grants	Structure for packaging focal plane imagers and signal processing circuits	US06/767063	Texas Instruments Incorporated
146	US20050151079	US	US Applications	Focal plane processor for ir detection	US10/511000	Semi Conductor Devices (scd) Partnership
147	WO2008118535	WO	WO Applications	Post-supported microbolometer pixel	US20080527	Bae Systems Information And Electronic Systems Integration Inc.
148	US6744068	US	US Grants	Active pixel sensor with intra-pixel charge transfer	US10/388250	California Institute Of Technology
149	US4720738	US	US Grants	Focal plane array structure including a signal processing system	US06/898890	Raytheon Company
150	CN101740501	CN	CN Patents	Photoelectrical p-n junction modification method of ion implantation type hgcdte infrared focal plane	CN200910198960	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
151	JP3839486	JP	JP Grants	Non cooling focal plane arrangement sensor	JP51676497	Lockheed Martin Love Ares Imaging Systems Inc
152	EP0529998	EP	EP Applications	Uncooled focal plane array.	EP92307730	Texas Instruments Incorporated
153	US6157404	US	US Grants	Imaging system including an array of dual-band microbridge detectors	US09/119158	Lockheed-martin Ir Imaging Systems, Inc.
154	US8283632	US	US Grants	Multi-color read-out integrated circuit	US11/529811	Teledyne Scientific & Imaging, Llc
155	US7852391	US	US Grants	Substitution of defective readout circuits in imagers	US10/011841	Bae Systems Information And Electronic Systems Integration Inc.
156	JP2008523772	JP	JP Applications	The imaging system which possesses the substitute redundant read-out ability of the read-out	JP2007546863	Bieii Information Systems And Electronic Systems Integrator Application Inc
157	CN101740501	CN	CN Patents	Photoelectrical p-n junction modification method of ion implantation type hgcdte infrared focal plane	CN200910198960	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
158	US4661168	US	US Grants	Method of integrating infrared sensitive image recording element with ccd on same substrate	US06/802601	Licentia Patent-verwaltungs-gmbh
159	US4956602	US	US Grants	Wafer scale testing of redundant integrated circuit dies	US07/310841	Amber Engineering, Inc.
160	US4654622	US	US Grants	Monolithic integrated dual mode ir/mm-wave focal plane sensor	US06/781557	Honeywell Inc.
161	WO2010056661	WO	WO Applications	High density composite focal plane array	US20090638	Bae Systems Information And Electronic Systems Integration Inc.
162	US5559332	US	US Grants	Thermal detector and method	US08/334666	L-3 Communications Corporation
163	US6136517	US	US Grants	Method for photo composition of large area integrated circuits	US09/036090	Raytheon Company
164	US6879923	US	US Grants	Digital offset corrector	US09/881648	Lockheed-martin Ir Imaging Systems, Inc.
165	US6509962	US	US Grants	Integrated circuit image sensor for wheel alignment systems	US09/566247	Hunter Engineering Company
166	US4445117	US	US Grants	Transistorized focal plane having floating gate output nodes	US06/335131	Hughes Aircraft Company, A Corp. Of De
167	US5426566	US	US Grants	Multichip integrated circuit packages and systems	US08/000826	International Business Machines Corporation
168	US6660988	US	US Grants	Detector selective fpa architecture for ultra-high fpa operability and fabrication method	US09/846726	Teledyne Scientific & Imaging, Llc
169	WO2004053443	WO	WO Applications	Thermal mismatch compensation technique for integrated circuit assemblies	US02389	Bae Systems Information And Electronic Systems Integration Inc
170	US5399989	US	US Grants	Voltage amplifying source follower circuit	US07/804346	Conexant Systems, Inc.
171	US7045761	US	US Grants	Self-pixelating focal plane array with electronic output	US10/873045	The Boeing Company
172	US6335478	US	US Grants	Thermopile infrared sensor, thermopile infrared sensors array, and method of manufacturing the same	US09/628677	Chou, Bruce S.c.
173	US4652901	US	US Grants	Infrared sensitive silicon substrate with integrated electronic processing devices and method for producing sa	US06/346730	Licentia Patent-verwaltungs-gmbh
174	CN1477859	CN	CN Patents	Flash electric charge amplification structure focal plane reading-out circuit and its reset reading-out method	CN03142613	Beijing Univ.
175	CN1203663	CN	CN Patents	Flash electric charge amplification structure focal plane reading-out circuit and its reset reading-out method	CN03142613	Beijing Univ.
176	JP2008134143	JP	JP Applications	Verification structure and verification method of infrared thermal image array module	JP2006320354	Ministry Of National Defense Chung Shan Inst Of Science & Technology
177	US7608823	US	US Grants	Multimode focal plane array with electrically isolated commons for independent sub-array biasing	US11/163022	Teledyne Scientific & Imaging, Llc
178	JP7128696	JP	JP Applications	Programmable focal plane signal processor and system	JP18378994	Internatl Business Mach Corp Lt;ibmgt;
179	CN102466521	CN	CN Patents	Tdi (time delay integration) scan imaging method for snapshot type area array infrared detector	CN201010540463	Nanjing University Of Science
180	US7858917	US	US Grants	Digital photon-counting geiger-mode avalanche photodiode solid-state monolithic intensity imaging focal-pla	US10/836896	Massachusetts Institute Of Technology
181	US20080121944	US	US Applications	Verification architecture of infrared thermal imaging array module	US11/604314	Chung Shan Institute Of Science And Technology
182	CN1900741	CN	CN Patents	High spectrum full polarization three dimension imaging integrate detecting system	CN200510086927	Beijing Univ. Of Aeronatucis And Astronatucis
183	US5740314	US	US Grants	Ir heating lamp array with reflectors modified by removal of segments thereof	US08/702746	Edison Welding Institute
184	WO9701926	WO	WO Applications	Digital offset corrector for microbolometer array	US96110	Lockheed Martin Ir Imaging Systems
185	US7462920	US	US Grants	Verification architecture of infrared thermal imaging array module	US11/604314	Chung Shan Institute Of Science And Technology
186	WO03029772	WO	WO Applications	Imaging array	US02299	Hrl Laboratories, Llc
187	US20110115916	US	US Applications	System for mosaic image acquisition	US12/619443	Pv Labs, Inc.
188	US20110272559	US	US Applications	Detector array for high speed sampling of a pulse	US12/776094	Flir Systems, Inc., Oregon
189	US20090237511	US	US Applications	Multi-window/multi-target tracking (mw/mt tracking) for point source objects	US12/050344	Bae Systems Information And Electronic Systems Integration Inc.
190	CN102288959	CN	CN Patents	A millimetric wave focal plane passive iamging system and method	CN201110164899	Beijing Institute Of Technology
191	US20030122079	US	US Applications	Millimeter wave imaging array	US10/256335	Hrl Laboratories, Llc
192	US20070076481	US	US Applications	Multimode focal plane array with electrically isolated commons for independent sub-array biasing	US11/163022	Teledyne Scientific & Imaging, Llc

193	US5438336	US	US Grants	Focal plane imaging array with internal calibration source	US08/151713	Northrop Grumman Systems Corporation
194	CN102565069	CN	CN Patents	Infrared microscopic non-destructive detector for integrated circuit	CN201110434080	Tianjin University Of Technology
195	US6147340	US	US Grants	Focal plane readout unit cell background suppression circuit and method	US09/163937	Raytheon Company
196	CN102809436	CN	CN Patents	One kind of infrared row of focal-plane reading circuits	CN201210289417	Wuxi Meng Involved In Sensing Technology Co Ltd
197	KR20120100643	KR	KR Patents	Infrared detector with semi-active focal plane array and method for manufacturing the same	KR20110019687	Korea Advanced Institute Of Science And Technology
198	CN101354288	CN	CN Patents	High speed low power consumption double-row line infrared focal plane read-out circuit	CN200810119756	Peking University
199	US5949483	US	US Grants	Active pixel sensor array with multiresolution readout	US08/785930	California Institute Of Technology
200	EP1928025	EP	EP Applications	Process control for the design and fabrication of thermal imaging array modules	EP060247	Chung Shan Institute Of Science And Technology
201	CN101354288	CN	CN Patents	High speed low power consumption double-row line infrared focal plane read-out circuit	CN200810119756	Peking University
202	US6329649	US	US Grants	Mm-wave/ir monolithically integrated focal plane array	US09/414988	Hrl Laboratories, Llc A Corporation Of California,
203	US7492400	US	US Grants	Adaptive pixel for high dynamic range and disturbance detection and correction	US10/858944	Board Of Trustees Of The Leland Stanford Junior University, The
204	CN100451678	CN	CN Patents	High spectrum full polarization three dimension imaging integrate detecting system	CN200510086927	Beijing Univ. Of Aeronatucis And Astronatucis
205	US6166768	US	US Grants	Active pixel sensor array with simple floating gate pixels	US08/785931	California Institute Of Technology
206	US6943838	US	US Grants	Active pixel sensor pixel having a photodetector whose output is coupled to an output transistor gate	US09/749989	California Institute Of Technology
207	US5539206	US	US Grants	Enhanced quantum well infrared photodetector	US08/425598	Lockheed Martin Corporation
208	US6693670	US	US Grants	Multi-photodetector unit cell	US09/629703	Vision - Sciences Inc.
209	US4416054	US	US Grants	Method of batch-fabricating flip-chip bonded dual integrated circuit arrays	US06/427333	Micron Technology, Inc.
210	US7489024	US	US Grants	Tmos-infrared uncooled sensor and focal plane array	US10/545892	Technion Research & Development Foundation Ltd
211	US8218012	US	US Grants	Multi-window/multi-target tracking (mw/mt tracking) method and system for point source objects	US12/050344	Bae Systems Information And Electronic Systems Integration Inc.
212	US8026471	US	US Grants	Single-photon avalanche detector-based focal plane array	US12/178329	Princeton Lightwave, Inc.
213	CN102410880	CN	CN Patents	Infrared focal plane array blind pixel detection method based on integral time adjustment	CN201110223261	Chongqing University Of Posts And Telecommunications
214	CN101876570	CN	CN Patents	Readout integrated circuit with automatic blind-pixel elimination function	CN201010142926	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
215	US20050224714	US	US Applications	Ultra low-cost uncooled infrared detector arrays in cmos	US11/100037	Akin, Tayfun
216	US20100019128	US	US Applications	Focal plane array imager	US12/178329	Princeton Lightwave, Inc.
217	US5627923	US	US Grants	Three-dimensional opto-electric integrated circuit using optical wiring	US08/307239	Hitachi, Ltd.
218	EP1282045	EP	EP Applications	Parallel processing logic circuit for sensor processing	EP024000	Nippon Telegraph And Telephone Corporation
219	US6369933	US	US Grants	Optical correlator having multiple active components formed on a single integrated circuit	US09/542554	Citizen Finetech Miyota Co., Ltd.
220	US5793322	US	US Grants	Successive approximation analog-to-digital converter using balanced charge integrating amplifiers	US08/744955	California Institute Of Technology, California
221	US20060244067	US	US Applications	Tmos-infrared uncooled sensor and focal plane array	US10/545892	Technion Research & Development Foundation Ltd
222	US6247037	US	US Grants	Optical correlator having multiple active components formed on a single integrated circuit	US09/238311	Micron Technology, Inc.
223	CN101358880	CN	CN Patents	Infrared focal plane read-out circuit and output stage structure thereof	CN200810119758	Peking University
224	WO2004075251	WO	WO Applications	Tmos-infrared uncooled sensor and focal plane array	IL20040001	Technion Research & Development Foundation Ltd.
225	CN202003246	CN	CN Patents	Bi-directional digital-type infrared focal plane temperature control system	CN201120047264	Overall System Of China Ministry Of Ordnance Industry
226	US5386128	US	US Grants	Monolithic in-based iii-v compound semiconductor focal plane array cell with single stage ccd output	US08/186185	United States Of America, The, As Represented By The Administrator Of The National Aeronautics And S
227	CN101358880	CN	CN Patents	Infrared focal plane read-out circuit and output stage structure thereof	CN200810119758	Peking University
228	US6274869	US	US Grants	Digital offset corrector	US09/981109	Lockheed-martin Ir Imaging Systems, Inc.
229	US5391875	US	US Grants	Infrared sensor package	US07/555867	Raytheon Company, A De Corp., Massachusetts
230	US7915585	US	US Grants	Microbolometer pixel and fabrication method utilizing ion implantation	US12/414766	Bae Systems Information And Electronic Systems Integration Inc.
231	US20100243896	US	US Applications	Microbolometer pixel and fabrication method utilizing ion implantation	US12/414766	Bae Systems Information And Electronic Systems Integration Inc.
232	US5237334	US	US Grants	Focal plane antenna array for millimeter waves	US07/876696	Waters; William M.
233	EP1637903	EP	EP Applications	Three-dimensional imaging processing module incorporating stacked layers containing microelectronic circuit	EP04104485	Ludwig, David E.
234	US6665013	US	US Grants	Active pixel sensor having intra-pixel charge transfer with analog-to-digital converter	US09/305346	California Institute Of Technology
235	US7411672	US	US Grants	Method and apparatus for chemical imaging in a microfluidic circuit	US11/824878	Chemimage Corporation
236	EP1007920	EP	EP Grants	Methods and circuitry for correcting temperature-induced errors in microbolometer focal plane array	EP98904855	Indigo Systems Corporation
237	WO02084741	WO	WO Applications	Monolithic infrared focal plane array detectors	US02117	Epir Ltd.
238	EP0857296	EP	EP Applications	Uncooled focal plane array sensor	EP969369	Lockheed-martin Ir Imaging Systems
239	JP5198848	JP	JP Applications	Focal plane-array	JP226004	Texas Instr Inc Lt;tigt;
240	US4780605	US	US Grants	Coherent light phase detecting focal plane charge-transfer-device	US07/121966	Lockheed Martin Corporation
241	US5925883	US	US Grants	Staring ir-fpa with ccd-based image motion compensation	US08/900408	Raytheon Company
242	CN101740502	CN	CN Patents	Light sensitive component array forming method of mercury cadmium telluride micro-table-board infrared de	CN200910198967	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
243	US7488926	US	US Grants	Pixel array with shared pixel output lines	US11/326354	Microsoft Corporation
244	US20030102432	US	US Applications	Monolithic infrared focal plane array detectors	US09/833363	Epir Technologies, Inc.
245	EP0242748	EP	EP Applications	Bipolar/mos input circuit for photovoltaic detectors.	EP871054	Honeywell Inc.
246	CN101740502	CN	CN Patents	Light sensitive component array forming method of mercury cadmium telluride micro-table-board infrared de	CN200910198967	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
247	US5459319	US	US Grants	Radiation detector circuit having a 1-bit quantized output	US07/159538	Boeing Company, The, A Corp. Of De
248	EP0870330	EP	EP Grants	Bolometric focal plane array	EP96929779	Lockheed-martin Ir Imaging Systems
249	US20060249658	US	US Applications	Method and apparatus for providing enhanced resolution in photodetectors	US11/125305	Sensors Unlimited, Inc.
250	US6657194	US	US Grants	Multispectral monolithic infrared focal plane array detectors	US09/834446	Epir Technologies, Inc.
251	FR2599529	FR	FR Patents	Method of integrating detection diode output currents into a monolithic integrated circuit and integrator for	FR86079	Telecommunications Sa
252	US5315147	US	US Grants	Monolithic focal plane array	US07/412161	Grumman Aerospace Corporation, 1111 Stewart Ave., Behtpage, Ny 11714-3580
253	US6906304	US	US Grants	Photo-sensor array for motion detection	US10/305062	Microsoft Corporation
254	US5185292	US	US Grants	Process for forming extremely thin edge-connectable integrated circuit structure	US07/802882	Harris Corporation
255	WO2011107487	WO	WO Applications	Focal plane array and method for manufacturing the same	EP2011053050	Sensonor Technologies As
256	WO2011107486	WO	WO Applications	Focal plane array and method for manufacturing the same	EP2011053049	Sensonor Technologies As
257	US6515285	US	US Grants	Method and apparatus for compensating a radiation sensor for ambient temperature variations	US09/502840	Bae Systems Information And Electronic Systems Integration Inc.

258	US6355939	US	US Grants	Multi-band infrared photodetector	US09/185262	Lockheed Martin Corporation
259	WO2005098380	WO	WO Applications	Ultra low-cost uncooled infrared detector arrays in cmos	EP2005051529	Akin, Tayfun
260	JP7154702	JP	JP Applications	Focal plane array integrated circuit for individually performing picture signal processing	JP174995	Texas Instr Inc Lt;tigt;
261	US6521477	US	US Grants	Vacuum package fabrication of integrated circuit components	US09/496820	L-3 Communications Corporation
262	US5489554	US	US Grants	Method of making a 3-dimensional circuit assembly having electrical contacts that extend through the ic laye	US08/192207	Tally Loch Investments Llc
263	US5729285	US	US Grants	Focal plane array integrated circuit with individual pixel signal processing	US08/474229	L-3 Communications Corporation
264	US5926217	US	US Grants	Focal plane array integrated circuit with individual pixel signal processing	US08/097522	L-3 Communications Corporation
265	US6317536	US	US Grants	Phased fiber array for multiplexing and demultiplexing	US09/445648	Corning Incorporated
266	US6080987	US	US Grants	Infrared-sensitive conductive-polymer coating	US08/958955	L-3 Communications Corporation
267	US6172417	US	US Grants	Integrated semiconductor devices	US08/535677	Lucent Technologies, Inc.
268	JP2004333132	JP	JP Applications	Thermal infrared solid-state imaging apparatus	JP2003124794	Mitsubishi Electric Corp
269	JP2008511042	JP	JP Applications	Lens control method and the device and camera module which installs this	JP2007530099	Panabijon Raiabiriti Imaging Company Ltd
270	US5471515	US	US Grants	Active pixel sensor with intra-pixel charge transfer	US08/188032	California Institute Of Technology
271	US7616877	US	US Grants	Method and apparatus for controlling a lens, and camera module incorporating same	US11/210022	Panavision Imaging, Llc
272	US7583074	US	US Grants	Low cost millimeter wave imager	US11/303642	Hrl Laboratories, Llc
273	JP8021767	JP	JP Applications	Infrared detector and preparation thereof	JP35830	Texas Instr Inc Lt;tigt;
274	CN1933149	CN	CN Patents	Backward integrated micro-lens infrared focal plane detector and micro-lens producing method	CN200610117106	Shanghai Inst. Of Technical Physics
275	US20120006971	US	US Applications	Radiation-hardened roic with tdi capability, multi-layer sensor chip assembly and method for imaging	US12/831694	Raytheon Company
276	JP6201457	JP	JP Applications	High-speed event detector and queuing sensor thereof	JP202952	Eiru Syst Inc
277	US20100309288	US	US Applications	3-dimensional hybrid camera and production system	US12/782845	Advanced Scientific Concepts, Inc.
278	US7777186	US	US Grants	Pixel interconnect insulators and methods thereof	US12/191596	L-3 Communications Cincinnati Electronics Corporation
279	US20100038539	US	US Applications	Pixel interconnect insulators and methods thereof	US12/191596	Cincinnati Electronics Corporation
280	EP0663696	EP	EP Grants	Thermal imaging device	EP953000	Raytheon Company
281	CN101103308	CN	CN Patents	Method and apparatus for controlling a lens, and camera module incorporating same	CN200580033219	Panavision Imaging Llc
282	EP1463960	EP	EP Grants	Dual mode adaptive threshold architecture for 3-d ladar focal plane array	EP037012	Raytheon Company
283	JP5027661	JP	JP Patents	Lens control method and the device and camera module which installs this	JP2007530099	Panavision Imaging Limited Liability Company
284	US7109488	US	US Grants	Multi-color infrared imaging device	US10/787907	Army, United States Of America As Represented By The Department Of The
285	US20120326124	US	US Applications	Frontside-illuminated inverted quantum well infrared photodetector devices	US13/605465	L-3 Communications Cincinnati Electronics Corporation
286	US20080316026	US	US Applications	Method and apparatus for detecting presence and range of a target object using a common detector	US11/812445	Lockheed Martin Corporation
287	US7332720	US	US Grants	Cold shield for cryogenic camera	US10/683073	Northrop Grumman Systems Corporation
288	CN101103308	CN	CN Patents	Method and apparatus for controlling a lens, and camera module incorporating same	CN200580033219	Panavision Imaging Llc
289	EP0721224	EP	EP Applications	Focal plane array for hybrid thermal imaging system and method	EP953095	Raytheon Company
290	EP0678756	EP	EP Applications	Staring focal plane array architecture for multiple applications.	EP951058	Raytheon Ti Systems, Inc.
291	US7235773	US	US Grants	Method and apparatus for image signal compensation of dark current, focal plane temperature, and electron	US11/104206	Exelis, Inc.
292	JP3998599	JP	JP Grants	Thermal infrared solid-state imaging apparatus	JP2003124794	Mitsubishi Electric Corp
293	EP0680101	EP	EP Grants	Thermal detector and method of making the same	EP953029	Raytheon Company
294	US20100038520	US	US Applications	Method and apparatus for detecting presence and range of a target object using a multimode detector	US12/581640	Lockheed Martin Corporation
295	CN201229510	CN	CN Patents	High precision temperature control device for infrared focus plane	CN200820068474	Hubei Grinds Plentiful Photoelectricity Science And Technology Co., Ltd.
296	US5485010	US	US Grants	Thermal isolation structure for hybrid thermal imaging system	US08/182868	L-3 Communications Corporation
297	CN101894848	CN	CN Patents	Tellurium-cadmium-mercury infrared focal plane integrated with anti-reflection film and method for preparin	CN201010198869	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
298	US5426304	US	US Grants	Infrared detector thermal isolation structure and method	US08/182865	Raytheon Company, A Corporation Of Delaware
299	US5436450	US	US Grants	Infrared detector local biasing structure and method	US08/182268	Raytheon Company, A Corporation Of Delaware
300	US20080208514	US	US Applications	Threat launch detection system and method	US11/588247	Bae Systems Information And Electronic Systems Integration Inc.
301	CN100444381	CN	CN Patents	Backward integrated micro-lens infrared focal plane detector and micro-lens producing method	CN200610117106	Shanghai Inst. Of Technical Physics
302	US7224009	US	US Grants	Method for forming a low leakage contact in a cmos imager	US11/128176	Micron Technology, Inc.
303	CN100433328	CN	CN Patents	Infrared focal plane detector with antireflective convergence microlens and microlens preparing method	CN200610118053	Shanghai Inst. Of Technical Physics, Cas
304	CN101201271	CN	CN Patents	Internal modulation type ferro-electricity non-refrigeration infrared focal plane prober	CN200710066481	Yunnan Nationalities University
305	CN1949508	CN	CN Patents	Infrared focal plane detector with antireflective convergence microlens and microlens preparing method	CN200610118053	Shanghai Inst. Of Technical Physics, Cas
306	CN101871817	CN	CN Patents	Hybrid-type pyroelectric uncooled focal plane detector and manufacturing process thereof	CN200910094401	Kunming Institute Of Physics
307	US7385199	US	US Grants	Microbolometer ir focal plane array (fpa) with in-situ mirco vacuum sensor and method of fabrication	US11/162849	Teledyne Scientific & Imaging, Llc
308	US5179283	US	US Grants	Infrared detector focal plane	US07/390058	Raytheon Company A Corporation Of Delaware
309	CN102509728	CN	CN Patents	Design and preparation method of non-refrigeration infrared detector	CN201110338955	Peking University
310	US20070075888	US	US Applications	Digital readout method and apparatus	US11/415007	Massachusetts Institute Of Technology, The
311	US20120193608	US	US Applications	Frontside-illuminated inverted quantum well infrared photodetector devices and methods of fabricating the	US13/019658	L-3 Communications Cincinnati Electronics Corporation
312	US5572059	US	US Grants	Thermal isolation of hybrid thermal detectors through an anisotropic etch	US08/477718	L-3 Communications Corporation
313	US5602392	US	US Grants	Thermal crosstalk reduction for infrared detectors with common electrodes	US08/476409	L-3 Communications Corporation
314	US5304791	US	US Grants	Apparatus for detecting high speed events	US07/919136	Ail Systems, Inc.
315	CN101201271	CN	CN Patents	Internal modulation type ferro-electricity non-refrigeration infrared focal plane prober	CN200710066481	Yunnan Nationalities University
316	US20090268069	US	US Applications	Photopumped semiconductor image amplifier with optical preamplification	US12/148970	Northrop Grumman Systems Corporation
317	CN1214480	CN	CN Patents	Apparatus which includes virtually imaged phased array (vipa) in combination with wavelength splitter to der	CN98119460	Fujitsu, Ltd.
318	EP0999599	EP	EP Applications	Optical cavity enhancement infrared photodetector	EP99250287	Lockheed Martin Corporation
319	CN101894848	CN	CN Patents	Tellurium-cadmium-mercury infrared focal plane integrated with anti-reflection film and method for preparin	CN201010198869	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
320	JP11223745	JP	JP Applications	Device equipped with virtual image phase array combined with wavelength demultiplexer for demultiplexing	JP285015	Fujitsu Ltd
321	US5309223	US	US Grants	Laser-based semiconductor lead measurement system	US07/719727	Cyberoptics Corporation
322	US5457318	US	US Grants	Thermal detector apparatus and method using reduced thermal capacity	US08/235413	L-3 Communications Corporation

323	US7245133	US	US Grants	Integration of photon emission microscope and focused ion beam	US10/985808	Dcg Systems, Inc.
324	WO2007085942	WO	WO Applications	Photodiode readout circuit	IB2007000165	Melexis Nv
325	US20070012870	US	US Applications	Analog bus driver and multiplexer	US11/454342	California Institute Of Technology
326	WO2006138564	WO	WO Applications	Analog bus driver and multiplexer	US20060234	California Institute Of Technology
327	US7579594	US	US Grants	Infrared radiation imager having sub-pixelization and detector interdigitation	US12/033648	Drs Sensors & Targeting Systems, Inc.
328	US20120001073	US	US Applications	Ir detector system and method	US13/203220	Selex Galileo Limited
329	CN1696658	CN	CN Patents	Multichannel detector module on focal plane of infrared ray and installation method	CN200510025915	Shanghai Inst Of Tech Physics, C.a.s
330	US7145124	US	US Grants	Multispectral imaging chip using photonic crystals	US10/941204	Raytheon Company
331	EP0644443	EP	EP Applications	Three-dimensional opto-electric integrated circuit using optical wiring.	EP941143	Hitachi, Ltd.
332	CN101872804	CN	CN Patents	Plasma backflow forming method for photoresist micro-convex lens array for mask	CN201010182280	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
333	CN201927607	CN	CN Patents	Photovoltaic mercury-cadmium-tellurium infrared focal plane integrated with antireflection coating	CN201020224891	Shanghai Institute Of Technical Physics Chinese Academy Of
334	US7339216	US	US Grants	Vertical color filter sensor group array with full-resolution top layer and lower-resolution lower layer	US11/285470	Foveon, Inc.
335	US4618763	US	US Grants	Infrared focal plane module with stacked ic module body	US06/722776	Grumman Aerospace Corporation
336	US5332899	US	US Grants	System for converting an infrared image into a visible or near infrared image	US08/063333	Commissariat A L'energie Atomique
337	US20050012033	US	US Applications	Digital photon-counting geiger-mode avalanche photodiode solid-state monolithic intensity imaging focal-pla	US10/836896	Massachusetts Institute Of Technology
338	US20120230602	US	US Applications	Multi-bank tdi approach for high-sensitivity scanners	US12/230100	Lockheed Martin Missiles And Fire Control
339	US20060054780	US	US Applications	Multispectral imaging chip using photonic crystals	US10/941204	Raytheon Company
340	US20030230722	US	US Applications	Ambient-to-cold focus and alignment of cryogenic space sensors using uncooled auxillary detectors	US10/171956	Raytheon Company
341	US20100046853	US	US Applications	Multi-bank tdi approach for high-sensitivity scanners	US12/230100	Lockheed Martin Missiles And Fire Control
342	US6021172	US	US Grants	Active pixel sensor having intra-pixel charge transfer with analog-to-digital converter	US08/567469	California Institute Of Technology
343	US8153978	US	US Grants	Dual color/dual function focal plane	US11/715617	Oceanit Laboratories, Inc.
344	US7791026	US	US Grants	Microbolometer infrared security sensor	US11/817165	
345	CN101871817	CN	CN Patents	Hybrid-type pyroelectric uncooled focal plane detector and manufacturing process thereof	CN200910094401	Kunming Institute Of Physics
346	CN1900740	CN	CN Patents	High spectrum full polarization imaging remote sensing system	CN200510086926	Beijing Univ. Of Aeronautics And Astronatucis
347	US6833547	US	US Grants	Ambient-to-cold focus and alignment of cryogenic space sensors using uncooled auxillary detectors	US10/171956	Raytheon Company
348	CN1067176	CN	CN Patents	Device for detecting deviation of pin of integrated circuit, and its data processing method	CN95102426	Daheng New Epoch Technology, Inc.
349	US5084704	US	US Grants	Focal plane analog-to-digital converter	US07/473742	Grumman Aerospace Corporation
350	US8076629	US	US Grants	Photopumped semiconductor image amplifier comprising a waveguide with embedded quantum wells and a	US12/148970	Northrop Grumman Systems Corporation
351	CN101833347	CN	CN Patents	Temperature drift reducing device and control method thereof	CN201010161729	University Of Electronic Science And Technology Of China
352	US20080135757	US	US Applications	Infrared radiation imager having sub-pixelization and detector interdigitation	US12/033648	Drs Sensors & Targeting Systems, Inc.
353	KR20070083593	KR	KR Patents	Method and apparatus for controlling a lens, and camera module incorporating same	KR20077006885	Panavision Imaging, Llc
354	US6157042	US	US Grants	Optical cavity enhancement infrared photodetector	US09/185249	Xylon Llc
355	JP3112105	JP	JP Grants	Semiconductor optical element	JP26640091	Nippon Telegr & Teleph Corp Lt;nttgt;
356	JP7087406	JP	JP Applications	Signal read circuit and its drive system	JP22994693	Nec Corp
357	JP5107420	JP	JP Applications	Semiconductor optical element	JP26640091	Nippon Telegr & Teleph Corp Lt;nttgt;
358	US6563947	US	US Grants	Application specified integrated circuit for use in wavefront detection	US09/459170	Technolas Perfect Vision Gmbh
359	US7351972	US	US Grants	Infrared radiation image having sub-pixelization and detector interdigitation	US11/206937	Drs Sensors & Targeting Systems, Inc.
360	US20090091752	US	US Applications	Apparatus and a method for inspection of a mask blank, a method for manufacturing a reflective exposure m	US12/241614	Renesas Electronics Corporation
361	US7394052	US	US Grants	Parallel processing logic circuit for sensor signal processing	US10/208527	Nippon Telegraph And Telephone Corporation
362	US4954708	US	US Grants	Low distortion focal plane platform	US07/397808	Santa Barbara Research Center, A Corp. Of Ca, Cali
363	US7911600	US	US Grants	Apparatus and a method for inspection of a mask blank, a method for manufacturing a reflective exposure m	US12/241614	Renesas Electronics Corporation
364	JP2000098148	JP	JP Applications	Ultra-fast optical signal processing circuit	JP262835	Nippon Telegr & Teleph Corp Lt;nttgt;
365	US6101232	US	US Grants	Active pixel sensor with intra-pixel charge transfer	US08/558521	California Institute Of Technology
366	US5972108	US	US Grants	Method of preferentially-ordering a thermally sensitive element	US08/910687	Texas Instruments Incorporated
367	US20070069133	US	US Applications	Microbolometer ir focal plane array (fpa) with in-situ micro vacuum sensor and method of fabrication	US11/162849	Teledyne Scientific & Imaging, Llc
368	EP0507541	EP	EP Grants	Infrared focal plane array processor with integrator and low pass filter per pixel	EP92302814	Raytheon Company
369	US20120133776	US	US Applications	Low contrast midwave flir implementation	US13/032819	Nova Research, Inc.
370	WO2007038191	WO	WO Applications	Microbolometer ir focal plane array (fpa) with in-situ micro vacuum sensor and method of fabrication	US20060367	Rockwell Scientific Licensing, Llc
371	US5945673	US	US Grants	Thermal detector with nucleation element and method	US08/919654	L-3 Communications Corporation
372	US5929800	US	US Grants	Charge integration successive approximation analog-to-digital converter for focal plane applications using a s	US08/906402	California Institute Of Technology
373	US5990481	US	US Grants	Thermal detector with preferentially-ordered thermally sensitive element and method	US08/919821	L-3 Communications Corporation
374	US20070012948	US	US Applications	Combined apd / pin ingaas photodetector with microlens structure and method of manufacture	US11/182493	Sensors Unlimited, Inc.
375	CN101561319	CN	CN Patents	Capacitive mems non-refrigerated infrared detector and preparation method thereof	CN200910085133	Peking University
376	WO02084740	WO	WO Applications	Multispectral monolithic infrared focal plane array detectors	US02114	Epir Ltd.
377	WO03106944	WO	WO Applications	Alignment of cryogenic infra-red sensors using uncooled auxillary detectors	US03189	Raytheon Company
378	US5844238	US	US Grants	Infrared imager using room temperature capacitance sensor	US08/622263	Sarnoff Corporation
379	US5315114	US	US Grants	Integrated circuit detector array incorporating bucket brigade devices for time delay and integration	US06/332039	Texas Instruments Incorporated; 13500 North Centra
380	US4703170	US	US Grants	Infrared focal plane module	US06/907408	Grumman Aerospace Corporation
381	US20050189492	US	US Applications	Multi-color infrared imaging device	US10/787907	Army, United States Of America As Represented By The Department Of The
382	JP3540687	JP	JP Grants	Optical signal processing circuit and its method	JP28114899	Nippon Telegr & Teleph Corp Lt;nttgt;
383	US8338200	US	US Grants	Frontside-illuminated inverted quantum well infrared photodetector devices and methods of fabricating the	US13/019658	L-3 Communications Cincinnati Electronics Corporation
384	WO02056076	WO	WO Applications	Fiber optic collimator array	US01513	Omm, Inc.
385	JPH11514084	JP	JP Applications	Non cooling focal plane arrangement sensor	JP51676497	Lockheed Martin Love Ares Imaging Systems Inc
386	JP2546514	JP	JP Grants	Signal read circuit and its drive system	JP22994693	Nippon Electric Co
387	US6483327	US	US Grants	Quadrant avalanche photodiode time-resolved detection	US09/409088	Globalfoundries Inc.

388	KR101158259	KR	KR Patents	Read out integrated circuit of infrared detection sensor and correcting method thereof	KR20110115234	Agency For Defense Development
389	WO2011064403	WO	WO Applications	Integrated circuit for spectral imaging system	EP2010068575	Imec
390	US5886659	US	US Grants	On-focal-plane analog-to-digital conversion for current-mode imaging devices	US08/916992	California Institute Of Technology
391	US20020025479	US	US Applications	Process for fabricating semiconductor integrated circuit device, and exposing system and mask inspecting me	US09/922656	Renesas Electronics Corporation
392	US20060038128	US	US Applications	Infrared radiation imager having sub-pixelization and detector interdigitation	US11/206937	Drs Sensors & Targeting Systems, Inc.
393	US6654057	US	US Grants	Active pixel sensor with a diagonal active area	US09/335182	Round Rock Research, Llc
394	US4611883	US	US Grants	Two-dimensional optics element for correcting aberrations	US06/551731	Hughes Electronics Corporation
395	WO2012005781	WO	WO Applications	Multi-mode seekers including focal plane array assemblies operable in semi-active laser and image guidance	US20110268	Raytheon Company
396	WO2012005781	WO	WO Applications	Multi-mode seekers including focal plane array assemblies operable in semi-active laser and image guidance	US20110268	Raytheon Company
397	US5572029	US	US Grants	Thermal isolation for hybrid thermal detectors	US08/488390	Texas Instruments Incorporated, A Corp. Of Delaware
398	US6522396	US	US Grants	Dual mode adaptive threshold architecture for 3-d ladar fpa	US10/040214	Raytheon Company
399	US20030160172	US	US Applications	Multispectral monolithic infrared focal plane array detectors	US09/834446	Epir Technologies, Inc.
400	US5308980	US	US Grants	Thermal mismatch accommodated infrared detector hybrid array	US07/928955	Amber Engineering, Inc.
401	US7808528	US	US Grants	Method and apparatus for an on-chip variable acuity imager array incorporating roll, pitch and yaw angle rate	US12/177048	Nova Research, Inc.
402	EP0768003	EP	EP Grants	Staring infrared focal plane array with on-focal plane array adaptive dynamic range control electronics	EP96915369	Raytheon Company
403	US5929433	US	US Grants	Reading device for a mosaic of electromagnetic detectors and detection system equipped with such a device	US08/880287	Commissariat A L'energie Atomique
404	JP2002258074	JP	JP Applications	Optical signal processing circuit	JP2001060967	Nippon Telegr & Teleph Corp Lt;nttgt;
405	WO9634490	WO	WO Applications	Staring infrared focal plane array with on-focal plane array adaptive dynamic range control electronics	US96058	Santa Barbara Research Center
406	US6921897	US	US Grants	Circuit and method for varying the integration time of moving charges from a photodetector	US09/666301	Lockheed Martin Corporation
407	US20040232335	US	US Applications	Microbolometer detector with high fill factor and transducers having enhanced thermal isolation	US10/441507	Flir Systems, Inc.
408	JP2001108861	JP	JP Applications	Optical signal processing circuit and its method	JP28114899	Nippon Telegr & Teleph Corp Lt;nttgt;
409	US5554849	US	US Grants	Micro-bolometric infrared staring array	US08/372982	Flir Systems, Inc.
410	US6121613	US	US Grants	Forward looking infrared device	US06/507628	Ol Security Limited Liability Company
411	US5081063	US	US Grants	Method of making edge-connected integrated circuit structure	US07/382388	Harris Corporation
412	IL124159	IL	IL Patents	Uncooled focal plane array sensor	IL124159	Bae Systems Information And Electronic Systems Integration Inc.
413	US6958478	US	US Grants	Microbolometer detector with high fill factor and transducers having enhanced thermal isolation	US10/441507	Flir Systems, Inc.
414	US6910096	US	US Grants	Sdram with command decoder coupled to address registers	US10/452339	Texas Instruments Incorporated
415	JP3515532	JP	JP Grants	Optical signal processing circuit	JP2001060967	Nippon Telegr & Teleph Corp Lt;nttgt;
416	US7408572	US	US Grants	Method and apparatus for an on-chip variable acuity imager array incorporating roll, pitch and yaw angle rate	US10/613126	Nova Research, Inc.
417	US5264699	US	US Grants	Infrared detector hybrid array with improved thermal cycle reliability and method for making same	US07/658985	Amber Engineering, Inc.
418	US6020216	US	US Grants	Thermal detector with stress-aligned thermally sensitive element and method	US08/920261	Texas Instruments Incorporated
419	US4831257	US	US Grants	Gate coupled input circuit	US06/912883	Loral Infrared & Imaging Systems, Inc.
420	WO2005062010	WO	WO Applications	Thermally stabilized radiation detector utilizing temperature controlled radiation filter	US20040406	Raytheon Company
421	EP0165312	EP	EP Applications	Pre-amplifier in focal plane detector array.	EP85900520	Irvine Sensors Corporation
422	US6809768	US	US Grants	Double slope pixel sensor and array	US09/494148	Foveon, Inc.
423	US5973311	US	US Grants	Pixel array with high and low resolution mode	US08/798852	Imation Corp., Minnesota
424	US6198101	US	US Grants	Integral charge well for a qwip fpa	US09/149483	Lockheed Martin Corporation
425	US20040061056	US	US Applications	Infrared detector array with improved spectral range and method for making the same	US10/259046	Flir Systems, Inc.
426	US5929434	US	US Grants	Ultra-low noise high bandwidth interface circuit for single-photon readout of photodetectors	US08/910342	Imperium (ip) Holdings
427	US4929913	US	US Grants	Gaas focal plane array readout	US07/393193	He Holdings, Inc., A Delaware Corp.
428	CN1193595	CN	CN Patents	Readout circuit of focal plane for quick-flasing charge amplifying structure and its readout method	CN03137083	Beijing Univ.
429	JP8050060	JP	JP Applications	Heat detector and manufacture therrof	JP106109	Texas Instr Inc Lt;tigt;
430	JP2000075333	JP	JP Applications	Optical signal processing circuit and optical signal processing method	JP24237598	Nippon Telegr & Teleph Corp Lt;nttgt;
431	CN1210548	CN	CN Patents	Reading circuit structure of double-colour line-array infrared focus plane detector	CN02145430	Shanghai Inst. Of Technical Physics, Chinese Academy Of Sciences
432	JP7324978	JP	JP Applications	Heat insulation structure for composite heat image pickup system and preparation there of	JP4469	Texas Instr Inc Lt;tigt;
433	CN101089658	CN	CN Patents	Method of non-refrigeration focal surface infrared cloud detection	CN200710025125	Meteorological College, Univ. Of Technology, Pla
434	US20120012748	US	US Applications	Architectures for imager arrays and array cameras	US13/106797	Pelican Imaging Corporation, California
435	JP7311083	JP	JP Applications	Manufacture of infrared detector and heat sensitive imaging system	JP4473	Texas Instr Inc Lt;tigt;
436	CN101420538	CN	CN Patents	Imaging circuit system for space multi-spectral linear array ccd remote sensor	CN200810239744	Beijing Space Electromechanical Research Institute
437	CN1412533	CN	CN Patents	Reading circuit structure of double-colour line-array infrared focus plane detector	CN02145430	Shanghai Inst. Of Technical Physics, Chinese Academy Of Sciences
438	JP2007527601	JP	JP Applications	Focal plane detector assembly of mass spectrometer	JP2007502023	Koporeishon Oi
439	CN100510781	CN	CN Patents	Method of non-refrigeration focal surface infrared cloud detection	CN200710025125	Meteorological College, Pla University Of Scienceand Technology
440	JP2002250828	JP	JP Applications	Optical signal processor and optical signal processing method	JP2002028826	Nippon Telegr & Teleph Corp Lt;nttgt;
441	WO0111694	WO	WO Applications	Flip-chip package with image plane reference	US00213	Silicon Film Technologies, Inc.
442	JP11295143	JP	JP Applications	Quick cooling cryostat for large infrared focal plane array	JP800017	Raytheon Co
443	US7309878	US	US Grants	3-d readout-electronics packaging for high-bandwidth massively paralleled imager	US10/901309	Energy, United States Department Of
444	CN101420538	CN	CN Patents	Imaging circuit system for space multi-spectral linear array ccd remote sensor	CN200810239744	Beijing Space Electromechanical Research Institute
445	EP1509754	EP	EP Applications	Focal plane processor for ir detection	EP03725553	Semi Conductor Devices (scd) Partnership
446	JP3520072	JP	JP Grants	Optical signal processor and optical signal processing method	JP2002028826	Nippon Telegr & Teleph Corp Lt;nttgt;
447	WO03103364	WO	WO Applications	Focal plane processor for ir detection	IL03004	Semi Conductor Devices (scd) Partnership
448	CN1945442	CN	CN Patents	System and method to correct for field curvature of multi lens array	CN200610142145	Asml Netherlands Bv
449	JP2006243734	JP	JP Applications	Wavelength-selective switch and integrated wavelength demultiplexer using stacked planar lightwave circuits	JP2006057054	Lucent Technol Inc
450	US5419637	US	US Grants	Method and apparatus for measuring temperature using an inherently calibrated p-n junction-type temperat	US08/147185	Ol Security Limited Liability Company
451	US4551629	US	US Grants	Detector array module-structure and fabrication	US06/572802	Irvine Sensors Corporation
452	JP4865365	JP	JP Patents	Wavelength-selective switch and integrated wavelength demultiplexer using stacked planar lightwave circuits	JP2006057054	Lucent Technol Inc

453	CN101561319	CN	CN Patents	Capacitive mems non-refrigerated infrared detector and preparation method thereof	CN200910085133	Peking University
454	CN201976195	CN	CN Patents	Continuous imager for all-time cloud coverage map	CN201020662494	Beijing Institute Of Spacecraft System Engineering
455	JP2007133382	JP	JP Applications	System and method to correct for field curvature of multilens array	JP2006274002	Asml Netherlands Bv
456	CN101078652	CN	CN Patents	Soi silicon wafer based non-refrigerating infrared sensor and its array and production method	CN200710098513	Tsinghua University
457	US5812190	US	US Grants	Detection method using distributed read and integration cycles for scanning camera and corresponding dete	US08/622609	Thomson-csf
458	EP1452895	EP	EP Applications	Optical signal processing apparatus and optical signal processing method	EP04012362	Nippon Telegraph And Telephone Corporation
459	US5452004	US	US Grants	Focal plane array imaging device with random access architecture	US08/079094	L-3 Communications Corporation
460	US5382797	US	US Grants	Fast cooldown cryostat for large infrared focal plane arrays	US07/632196	Santa Barbara Research Center
461	EP1452894	EP	EP Applications	Optical signal processing apparatus and optical signal processing method	EP04012361	Nippon Telegraph And Telephone Corporation
462	US7501634	US	US Grants	Method and system for distribution of an exposure control signal for focal plane arrays	US10/742285	Massachusetts Institute Of Technology
463	EP1246121	EP	EP Applications	Dynamically reconfigurable signal processing circuit, pattern recognition apparatus, and image processing ap	EP02252197	Canon Kabushiki Kaisha
464	WO2012005749	WO	WO Applications	Radiation-hardened roic with tdi capability, multi-layer sensor chip assembly and method for imaging	US20110007	Raytheon Company
465	EP0645925	EP	EP Applications	A signal readout circuit and its drive circuit.	EP94114560	Nec Corporation
466	US6822213	US	US Grants	Image sensors with improved signal to noise ratio	US10/440331	Vision - Sciences Inc
467	US20110303846	US	US Applications	Ir detector system and method	US13/202916	Selex Galileo Limited
468	CN102122762	CN	CN Patents	Millimeter-wave 360-deg omnidirectional-scan dielectric cylinder lens antenna	CN201110026393	Zhejiang University
469	US7417230	US	US Grants	Microbolometer focal plane array with temperature compensated bias	US11/530697	Fluke Corporation
470	US8179296	US	US Grants	Digital readout method and apparatus	US11/415007	Massachusetts Institute Of Technology, The
471	US5909026	US	US Grants	Integrated sensor with frame memory and programmable resolution for light adaptive imaging	US08/867835	California Institute Of Technology, California
472	US4902894	US	US Grants	Gate coupled input circuit	US06/912885	Honeywell Inc.
473	WO2012135542	WO	WO Applications	Dual well read-out integrated circuit (roic)	US20120312	Flir Systems, Inc.
474	JP2001289712	JP	JP Applications	Method for correcting video signal of infrared sensor and imaging system	JP2001058540	Boeing Co:the
475	US7750301	US	US Grants	Microbolometer optical cavity tuning and calibration systems and methods	US11/865927	Flir Systems, Inc.
476	WO9718589	WO	WO Applications	A dual-band multi-level microbridge detector	US96186	Lockheed-martin Ir Imaging Systems, Inc.
477	TW569006	TW	TW Patents	Millimeter wave imaging array	TW911219	Hrl Laboratories, Llc
478	US20040195509	US	US Applications	Qwip with tunable spectral response	US10/829574	Schilmass Co. L.l.c.
479	EP0849802	EP	EP Applications	Low-crosstalk differencing circuit architecture for integrated two-color focal plane arrays	EP973101	Raytheon Company
480	US5880777	US	US Grants	Low-light-level imaging and image processing	US08/632746	Massachusetts Inst. Of Technology, Massachusetts
481	EP0635885	EP	EP Applications	High density circuit assembly and method of forming the same.	EP93305793	Raytheon Company
482	WO2010053780	WO	WO Applications	Signal processor with analog residue	US20090623	Raytheon Company
483	US6900839	US	US Grants	High gain detector amplifier with enhanced dynamic range for single photon read-out of photodetectors	US09/675487	Altasens, Inc.
484	CN102692276	CN	CN Patents	One kind of non-refrigeration infrared acquisition aid	CN201110069273	Zhejiang Dali Technology Co Ltd
485	WO9728641	WO	WO Applications	Active pixel sensor array with multiresolution readout	US97010	California Institute Of Technology
486	EP0940029	EP	EP Applications	Active pixel sensor array with multiresolution readout	EP97903909	California Institute Of Technology
487	US3963920	US	US Grants	Integrated optical-to-electrical signal transducing system and apparatus	US05/556612	Hughes Missile Systems Company
488	US4684800	US	US Grants	Low-noise charge-injection method and apparatus for ir ccd scanning	US06/839398	He Holdings, Inc., A Delaware Corp.
489	JP3428374	JP	JP Grants	Millimeter wave image system	JP147045	Omron Corp
490	US4628933	US	US Grants	Method and apparatus for visual prosthesis	US06/758609	Regents Of The University Of California, The, A Corp. Of Ca
491	US4611124	US	US Grants	Fly's eye sensor nonlinear signal processing	US06/620211	The United States Of America As Represented By The Secretary Of The Air Force
492	US20100252736	US	US Applications	Imaging system	US12/745860	Selex Galileo Limited
493	US6547406	US	US Grants	Infra-red imaging systems and other optical systems	US09/529671	Qinetiq Limited
494	IL122556	IL	IL Patents	Low-crosstalk column differencing circuit architecture for integrated two-color focal plane arrays	IL122556	Raytheon Company
495	US8093559	US	US Grants	Methods and apparatus for three-color infrared sensors	US12/326883	Hrl Laboratories, Llc, California
496	CA2220834	CA	CA Patents	Enhanced quantum well infrared photodetector	CA2220834	Loral Vought Systems Corporation
497	US4956716	US	US Grants	Imaging system employing charge amplifier	US07/312262	Santa Barbara Research Center, California
498	US6884636	US	US Grants	Method of fabrication of an infrared radiation detector and infrared detector device	US09/861334	Canadian Imperial Bank Of Commerce, As Security Ag
499	CA2467160	CA	CA Patents	Microbolometer detector with high fill factor and transducers having enhanced thermal isolation	CA24671	Institut National D'optique
500	WO2012170946	WO	WO Applications	Low power and small form factor infrared imaging	US20120417	Flir Systems, Inc.
501	CN101958330	CN	CN Patents	Mercury cadmium telluride (hgcdte) photovoltaic detection chip for metalized common ion implantation win	CN201010234857	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
502	CA2467160	CA	CA Patents	Microbolometer detector with high fill factor and transducers having enhanced thermal isolation	CA24671	Institut National D'optique
503	IL122556	IL	IL Patents	Low-crosstalk column differencing circuit architecture for integrated two-color focal plane arrays	IL122556	He Holdings, Inc. Dba Hughes Electronics
504	US5983320	US	US Grants	Method and apparatus for externally configuring and modifying the transaction request response characteris	US08/910810	Rambus, Inc.
505	JP8062037	JP	JP Applications	Infrared detector	JP225737	Murata Mfg Co Ltd
506	JP57029005	JP	JP Applications	Optical branching filter	JP10357480	Nippon Telegr & Teleph Corp <ntt>

Chinese ROIC and Infrared Focal Plane Array Patents

as of 3 January 2013

(This is not an exhaustive list, it is a sampling)

Publication No.	Country	Source	Title	APP No.	Assignee
CN102095501	CN	CN Patents	Irfpa (infrared focal plane array) and read-out circuit thereof	CN201010570406	Beijing Guangwei Integrated Circuit Inc.
CN102095501	CN	CN Patents	Irfpa (infrared focal plane array) and read-out circuit thereof	CN201010570406	Beijing Guangwei Integrated Circuit Inc.
CN102447845	CN	CN Patents	Infrared focal plane array readout circuit and adaptive power consumption regulation method thereof	CN201110299627	Peking University
CN2754070	CN	CN Patents	Background current inhibition reading-out circuit for infrared focal plane array	CN200420061801	Chongqing Univ.
CN101246047	CN	CN Patents	Infrared focal plane array dark field current compensation circuit and method thereof	CN200710049358	University Of Electronic Science And Technology Of China
CN100587419	CN	CN Patents	Infrared focal plane array dark field current compensation circuit	CN200710049358	University Of Electronic Science And Technology Of China
CN101635295	CN	CN Patents	Quantum well infrared focal plane array and manufacturing method	CN200910041873	Sun Yat-sen University
CN102494784	CN	CN Patents	Readout circuit and readout method for point-by-point bias correction data of infrared focal plane array im	CN201110419260	University Of Electronic Science And Technology Of China
CN102564599	CN	CN Patents	Readout circuit in infrared focal plane array and reference resistor of readout circuit as well as manufacturi	CN201110437202	University Of Electronic Science And Technology Of China
CN101635295	CN	CN Patents	Quantum well infrared focal plane array and manufacturing method	CN200910041873	Sun Yat-sen University
CN102589718	CN	CN Patents	Reading method of silicon substrate focal plane device	CN201210045860	Zhang Kang
CN102589719	CN	CN Patents	Reading circuit of silicon substrate focal plane device	CN201210045862	Zhang Kang
CN102214662	CN	CN Patents	Monolithic integration structure of un-cooled infrared focal plane array detector and manufacturing metho	CN201110105424	Peking University
CN1165078	CN	CN Patents	Pixel array layout method and metal wire structure for focal plane read-out circuit	CN01134707	Beijing University
CN102280456	CN	CN Patents	An infrared focal plane array probe integrated structure and preparation method	CN201110121051	Peking University
CN1348209	CN	CN Patents	Pixel array layout method and metal wire structure for focal plane read-out circuit	CN01134707	Beijing Univ.
CN202120912	CN	CN Patents	Non-refrigeration infrared focal plane array detector	CN201120147997	Ir Co Ltd Wuhan High German
CN101995295	CN	CN Patents	Non-refrigerating infrared focal plane array as well as preparation method and application thereof	CN200910090545	Peking University
CN102280455	CN	CN Patents	Non-a is made the cooled infrared focal plane array probe	CN201110120925	Ir Co Ltd Wuhan High German
CN101825516	CN	CN Patents	Device and method for testing infrared focal plane array device	CN201010161721	University Of Electronic Science And Technology Of China
CN102384789	CN	CN Patents	Infrared focal plane array device and manufacture method thereof	CN201010267982	Institute Of Microelectronics Chinese Academy Of Sciences
CN101242495	CN	CN Patents	Self-adapted digitalization method and its circuit for infrared plane array	CN200710020008	Nanjing University Of Science And Technology
CN100544411	CN	CN Patents	Self-adapted digitalization method and its circuit for infrared plane array	CN200710020008	Nanjing University Of Science And Technology
CN101740501	CN	CN Patents	Photoelectrical p-n junction modification method of ion implantation type hgcdte infrared focal plane	CN200910198960	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN101740501	CN	CN Patents	Photoelectrical p-n junction modification method of ion implantation type hgcdte infrared focal plane	CN200910198960	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN1477859	CN	CN Patents	Flash electric charge amplification structure focal plane reading-out circuit and its reset reading-out metho	CN03142613	Beijing Univ.
CN1203663	CN	CN Patents	Flash electric charge amplification structure focal plane reading-out circuit and its reset reading-out metho	CN03142613	Beijing Univ.
CN102565069	CN	CN Patents	Infrared microscopic non-destructive detector for integrated circuit	CN201110434080	Tianjin University Of Technology
CN102809436	CN	CN Patents	One kind of infrared row of focal-plane reading circuits	CN201210289417	Wuxi Meng Involved In Sensing Technology Co Ltd
CN101354288	CN	CN Patents	High speed low power consumption double-row line infrared focal plane read-out circuit	CN200810119756	Peking University
CN101354288	CN	CN Patents	High speed low power consumption double-row line infrared focal plane read-out circuit	CN200810119756	Peking University
CN102410880	CN	CN Patents	Infrared focal plane array blind pixel detection method based on integral time adjustment	CN201110223261	Chongqing University Of Posts And Telecommunications
CN101876570	CN	CN Patents	Readout integrated circuit with automatic blind-pixel elimination function	CN201010142926	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN101358880	CN	CN Patents	Infrared focal plane read-out circuit and output stage structure thereof	CN200810119758	Peking University
CN202003246	CN	CN Patents	Bi-directional digital-type infrared focal plane temperature control system	CN201120047264	Overall System Of China Ministry Of Ordnance Industry
CN101358880	CN	CN Patents	Infrared focal plane read-out circuit and output stage structure thereof	CN200810119758	Peking University
CN101894848	CN	CN Patents	Tellurium-cadmium-mercury infrared focal plane integrated with anti-reflection film and method for prepa	CN201010198869	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN1949508	CN	CN Patents	Infrared focal plane detector with antireflective convergence microlens and microlens preparing method	CN200610118053	Shanghai Inst. Of Technical Physics, Cas
CN101871817	CN	CN Patents	Hybrid-type pyroelectric uncooled focal plane detector and manufacturing process thereof	CN200910094401	Kunming Institute Of Physics
CN102509728	CN	CN Patents	Design and preparation method of non-refrigeration infrared detector	CN201110338955	Peking University
CN101894848	CN	CN Patents	Tellurium-cadmium-mercury infrared focal plane integrated with anti-reflection film and method for prepa	CN201010198869	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN1696658	CN	CN Patents	Multichannel detector module on focal plane of infrared ray and installation method	CN200510025915	Shanghai Inst Of Tech Physics, C.a.s
CN201927607	CN	CN Patents	Photovoltaic mercury-cadmium-tellurium infrared focal plane integrated with antireflection coating	CN201020224891	Shanghai Institute Of Technical Physics Chinese Academy Of
CN101872804	CN	CN Patents	Plasma backflow forming method for photoresist micro-convex lens array for mask	CN201010182280	Shanghai Institute Of Technical Physics, Chinese Academy Of Sciences
CN1067176	CN	CN Patents	Device for detecting deviation of pin of integrated circuit, and its data processing method	CN95102426	Daheng New Epoch Technology, Inc.
CN101833347	CN	CN Patents	Temperature drift reducing device and control method thereof	CN201010161729	University Of Electronic Science And Technology Of China
CN101561319	CN	CN Patents	Capacitive mems non-refrigerated infrared detector and preparation method thereof	CN200910085133	Peking University
CN1193595	CN	CN Patents	Readout circuit of focal plane for quick-flasing charge amplifying structure and its readout method	CN03137083	Beijing Univ.
CN1210548	CN	CN Patents	Reading circuit structure of double-colour line-array infrared focus plane detector	CN02145430	Shanghai Inst. Of Technical Physics, Chinese Academy Of Sciences
CN101089658	CN	CN Patents	Method of non-refrigeration focal surface infrared cloud detection	CN200710025125	Meteorological College, Univ. Of Technology, Pla
CN1412533	CN	CN Patents	Reading circuit structure of double-colour line-array infrared focus plane detector	CN02145430	Shanghai Inst. Of Technical Physics, Chinese Academy Of Sciences

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Washington, DC 20230

and

Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
Bureau of Political Military Affairs
Department of State
Washington, DC 20522

Subjects: RIN 0694-AF75 - Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the United States Munitions List (USML)

and RIN 1400-AD32 Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

Dear Sir or Madam:

Fluke Corporation is pleased to have the opportunity to provide feedback on the Administration's proposed rule, Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII ("Proposed Rule") and complementary revisions to the Export Administration Regulations ("EAR Revisions"). This comment focuses on proposed changes to controls related to commercial thermal imaging cameras and addresses certain apparent shortcomings with respect to several of the stated goals of the Administration's rulemaking.

Fluke is concerned that the Proposed Rule identifies items for control on the United States Munitions List ("USML") that are not controlled on the Wassenaar Arrangement's Munitions List ("WAML"), does not establish a bright line between the USML and Commerce Control List ("CCL"), and controls items on the International Traffic in Arms ("ITAR") that are in normal commercial use and have foreign availability. Additionally, the EAR Revisions creates new controls on items that were not previously controlled, increases licensing requirements, removes availability of license exceptions and even imposes a presumption of denial for certain items, all of which appear to be contrary to Export Control Reform ("ECR").

The rewrite of USML Category XII and complementary EAR Revisions was initiated to protect the commodities and components most important to our military, while providing relief to companies struggling with outdated and overly burdensome regulations by placing less sensitive items on the more flexible CCL. This Proposed Rule falls significantly short of both of these goals.

Rather than providing a bright jurisdictional line between the CCL and the USML, the proposed revisions will lead to increased confusion, and enforce expansive restrictions that place heavier burdens on U.S. originated products. Many of these restrictions will place greater constraints on items that have non-military commercial applications and are readily available in foreign markets.

Under the current export control model, the U.S. thermal imaging industry is already at a competitive disadvantage against our foreign competitors. To be more competitive with foreign competitors, U.S. companies must find ways to reduce the impact of export control licensing hurdles. Therefore, many U.S. multi-national companies have chosen to move research, development and manufacturing to off-shore subsidiaries outside the U.S., and in some cases U.S. companies are fully outsourcing these functions to non-U.S. companies.

While the stated goal of maintaining strict export controls around thermal imaging technology is to preserve U.S. technological and tactical advantages, we are concerned that these changes will ultimately backfire, and lead to U.S. dependence on foreign technology. The impact of these decisions will be felt by the U.S. commercial base and the U.S. Government. Advanced thermal imaging technology and products will soon be dominated by foreign industries. U.S. consumers – including the U.S. Government - will have to pay more for products produced outside the U.S. and the U.S. Government may lose access to domestic sources of the newest technologies, may become reliant on foreign sources for a critical tactical capability, and our war-fighters ultimately may be put at a disadvantage. Additionally, the proposed licensing requirements for EAR items will dramatically limit U.S. companies ability to compete with European competitors.

Fluke Corporation supports the U.S. Government's desire to protect U.S. technology and national security. Export controls play an important part in this endeavor. However, if the regulations are not carefully drafted to limit the strictest controls to products and technology that are critical to our national security, are equally protected by our allies, are not already in commercial use, and are not readily available in foreign markets, export controls begin to have the opposite effect.

The Sensors and Instrumentation Technical Advisory Committee ("SITAC"), amongst other advisory and industry groups, have been working with the Departments of State, Defense and Commerce for several years to develop U.S. export controls for thermal imaging products and technology that meet U.S. national security needs , are aligned with the Wassenaar Arrangement controls, and are practical for the U.S. industry. The SITAC is comprised of representatives from the world's best thermal imaging companies, currently based in the United States. These representatives, mostly highly skilled engineers, have proposed regulations that meet the goals of U.S. export control reform, but very few, if any of these recommendations are reflected in the proposed rules. Fluke Corporation supports technical recommendations by the SITAC and other technical advisory committees and respectfully asks that DDTC and BIS accord the recommendations of these committees greater weight when developing alternatives to the current proposed changes to Category XII and complementary provisions of the EAR.

A. HARDWARE - INFRARED FOCAL PLAY ARRAYS, CORES AND CAMERAS

I. The Proposed Rule Identifies Items for USML Control that are not controlled on the Wassenaar Arrangement's Munitions List

Category XV of the WAML controls, inter alia, Infrared or thermal imaging equipment, specially designed for military use, and specially designed components and accessories therefor. A number of the items described in the Proposed Rule are in normal commercial use throughout the world and are not currently controlled on the USML nor are they described on the WAML. Specific examples of these items are described below in section III.

II. The Proposed Rule Does Not Establish a Bright Line Between the USML and CCL

a. Integration of an IRFPA into a permanent encapsulated sensor assembly as a control parameter in Category XII (c) is not technically sound and will increase the need for CJs

Instead of providing a "bright line" for Infrared Focal Play Arrays ("IRFPAs"), the attempt in subparagraph (c)(2)-(6) to draw a jurisdictional line for IRFPAs by distinguishing those in a "permanent encapsulated sensor assembly" from those that are not creates a vast gray zone and an increased need for Commodity Jurisdiction Requests ("CJs"). This approach is flawed on several levels:

1. It has nothing to do with utility of IRFPAs for military versus civil applications. Packaging/encapsulating an IRFPA does nothing to make it more useful or appropriate for civil applications or any less useful or appropriate for military applications. Indeed, IRFPAs have well-established utility in both civil and military applications; they are inherently dual use and do not warrant control on the USML Attempting to draw a line between the "raw" IRFPA and a packaged IRFPA does nothing to change the fact that IRFPA's are inherently dual use items.

2. There's no clear reason why the controls or jurisdictions should be different for the packaging versus the IRFPA die. The IRFPA package/encapsulation and the technology to make it is generally equally important in achieving the overall function and performance of an IRFPA as the technology to make the FPA die that goes into the package. In the case of uncooled microbolometers, without the vacuum package there is no meaningful IR responsivity whatsoever. Said another way, without the vacuum package, the FPA die is really not an IRFPA at all. In the case of cooled, photon-detection IRFPAs, without the package the device could not be cooled to the necessary operating temperature without moisture or frost that would render it inoperable. (As a side note, it could be argued that, for at least these reasons, the pre-packaged/encapsulated arrays would be more properly classified and treated as components, not finished IRFPAs.)

3. The gray zone created by the proposed regulations would be especially difficult for wafer-level or pixel-level packaged microbolometer IRFPAs. With wafer-level and pixel-level integral vacuum packaging technologies, the FPA die itself forms a portion of the vacuum package. With wafer-level packaging, the FPA wafer is mated and sealed to a corresponding "top-cap" wafer that is manufactured using similar IC and MEMS processing technologies as are used for the underlying ROIC/FPA wafer—often all of the steps being accomplished in the same IC/MEMS foundry.[1] There are packaging features and technology intermixed into the underlying FPA/ROIC wafer (e.g., the die itself forms the lower portion of the package, metal seal rings and getter layers are deposited on it, etc.) and, vice versa, there are pixel/FPA features in the top-cap window that are integral to the underlying FPA (e.g., features that complete the shielding for "blind" reference pixels that are needed for ambient temperature compensation.) With pixel-level packaging, MEMS processing techniques are used to create a tiny, individual micro-package around each pixel. Incidentally, the most advance work on pixel-level packaging for IRFPAs appears to be occurring outside the U.S.[2] Further, because of the precise spatial registration and correspondence needed amongst all the features, the entire set of mask designs, from the first ROIC layer all the way through to the last top-cap layer, are generally contained in a single CAD file. The proposed regulations would create an immediate need for numerous CJs to resolve this ambiguity for wafer-level and pixel-level uncooled microbolometer IRFPAs and the associated technologies to make them.

4. It is not clear that technology to create the high-integrity vacuum packaging that's needed for IRFPAs is any more or less widely available than the technology to make the pre-packaged FPA die. Indeed, there are many outside-the-U.S. ("O.U.S.") sources of IRFPAs, including several in non-WA countries (more on this below).

Note 1 to paragraph (c) doesn't help resolve any of the above and adds its own problems by not being clear (no bright line) in the following ways:

1. Regarding what constitutes "direct access to the IRFPA" and/or how to prevent it. Certainly "direct access" cannot mean optical or electrical access or there would be no way to use the encapsulated IRFPA.

2. Regarding what level of effort, due diligence and engineering is required to render an IRFPA sufficiently tamper proof to meet the requirements of Note 1.

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[1] Early (1993) Honeywell patent on wafer level packaging for IRFPAs provides good overview of the concept. Of note, this is referenced by 110+ other patents, including numerous from outside the US; a good understanding of WLP can be obtained by following these 110+ links, available at https://www.google.com/patents/US5895233?dq=US5895233&hl=en&sa=X&ei=VyeTVb3VHJHaoASVkZnAAQ&ved=0CB0Q6AEwAA

[2] An example of LETI/ULIS pixel level packaging is available at http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1387339&resultClick=1

3. Regarding who has the burden of proof, what level of testing and analysis would be sufficient, and what the criteria would be required to meet Note 1.

All of the above would lead to multiple CJ requests to verify whether there is direct access to the IRFPA.

The definition of "multispectral" and associated controls proposed in (c)(6) are vague and thus do not provide a "bright line." The term "discrete output" in the definition of "multispectral" should be clarified. It is unclear if the following examples of IRFPAs would fall within this definition: (1) a broadband IRFPA integrally fitted with a filter or lenslet array with different band-pass characteristics for each of the lens/filter elements; i.e., analogous to a Bayer filter; (2) a microbolometer IRFPA where pixels have varying resonant absorption cavities that create varying spectral response.

III. The Proposed Rule Controls Items on the ITAR that are in Normal Commercial Use

a. Incorporation of an IRFPA into an infrared imaging camera core as a control parameter is not technically sound and will increase controls on cores in normal commercial use

The proposed inclusion of infrared camera cores in sub-category (c)(12) adds items on the USML that are in normal commercial use and creates ambiguity. Like IRFPAs, "cores" have well-established utility in both civil/commercial and military applications; they are inherently dual use and do not warrant control on the USML. Most importantly, IRFPAs are widely available, including in non-WA countries.[3]

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[3] China (GWIC, etc) – Excerpts: ***Currently more than five Chinese companies*** and institutions design and fabricate uncooled infrared focal plane array. Some devices have sensitivity as high as 30 mK; the largest array ***for commercial products*** is 640×512 and the smallest pixel size is 17 µm. See Uncooled infrared focal plane array imaging in China.

China – (DALI) Excerpt: Since 2006, Dali…has brought several uncooled detectors into mass production, including 35um 384x288, 25um 160x120, 384x288, 640x480, and 17um 384x288, 640x480. See Uncooled infrared detector and imager development at DALI Technology.

Turkey (Mikrosens) – See A miniature low-cost LWIR camera with a 160×120 microbolometer FPA.

Israel (SCD) – Very wide range of IRFPAs commercially available, SWIR, MWIR and LWIR, **up to 1024x768**. (Note, website is for "SCD-USA LLC" but this is just a US sales/support office, these IRFPAs are all developed and manufactured in Israel). See http://www.scdusa-ir.com/ir-sensors/

France (ULIS) – In volume production with a wide range of a-Si uncooled microbolometer IRFPAs, **up to 1024x768**. See http://www.ulis-ir.com/index.php?infrared-detector=products.

France (Sofradir) – Very wide range of photon-detector IRFPAs for MWIR and LWIR – MCT, InSb, InGaAs and QWIP. See http://www.sofradir.com/.

Further (c)(12) has the following additional problems:

1. It appears as though a "core" ("e.g., module, engine, kit") is intended to represent some key subset of a camera but, defined as is proposed, **there is no meaningful difference between a "core" and a general-purpose camera**—certainly no "bright line." This flaw ultimately makes (c)(12) both potentially overly broad (capturing civil/commercial cameras) and ineffective (failing to capture possible defense items). Consider the following example: A "core" consisting of a 1024x768 pixel microbolometer IRFPA along with a specially designed lens and PCA/electronics. Suppose the electronics include an input connector for power and an output connector that provides imagery via a standard interface and format (e.g. HDMI). This "core" would appear to be captured under subparagraph (iii) of (c)(12). Consider now a general-purpose IR camera made from this core by adding a housing that is back-filled with epoxy potting compound so the IRFPA, lens and PCA cannot be removed without destruction or damage to the "core." Following Note 2 to paragraph (c)(12), this general-purpose camera would now be EAR controlled; however, there is no meaningful functional difference whatsoever between it and its ITAR-controlled "core." Ironically, the added ruggedness provided by the housing and potting might in fact make this "camera" even more suitable for military uses than its "core."

2. Indeed, *any* infrared camera, system or product will inevitably include at least enough electronics "to enable as a minimum the output of an analog or digital signal once power is applied;" i.e., to comprise a "core." Therefore *any* such camera, system or product that has an IRFPA or other characteristic that meets the criteria identified in the eleven sub-items to paragraph (c)(12) will ultimately be ITAR controlled unless modified in some way (i.e., made tamper proof) to meet Note 2 to paragraph (c). There are numerous existing civil/commercial IR camera systems that are not presently tamper proof per Note 2 that will become ITAR controlled under the proposed paragraph (c)(12). One example is the Fluke TiX1000 (1024x768 civil/commercial camera).[4]

3. Modifying civil/commercial IR camera designs to make them tamper proof per Note 2 to paragraph (c) would be a tremendous burden on U.S. industry that would make U.S. IR camera products more difficult and expensive to manufacture and difficult or impossible

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Belgium (Xenics) -- 640 x 512 InGaAs (SWIR) detector with 20 µm pixel pitch. See http://www.xenics.com/en/xfpa-17-640-ln2; http://www.xenics.com/en/xlin-detector-series; http://www.xenics.com/en/xlin-17-3000

Germany (Bosch) – Low-cost 82x62 uncooled thermo-diode IRFPA. See http://www.bosch-semiconductors.de/media/pdf_1/press_releases/SMO130_Productinfo_1402.pdf.

Canada (INO). See http://www.ino.ca/media/187149/datsheet-384x288-fpa.pdf.

South Korea (I3 System) – Locally developed cooled MWIR/LWIR and uncooled LWIR. See http://www.i3system.com/eng/n_product/product111.html; http://www.i3system.com/eng/n_product/product121.html

[4] See, for example, above references for ULIS and SCD.

to service—ultimately making U.S. products less competitive globally. Further, it is not at all clear (no bright line) on what level of effort, due diligence and engineering is required to render an item sufficiently tamper proof to meet the requirements of Note 2.

4. The weapon shock load event control parameter described in subparagraph (ii) is problematic on many levels. Many civil/commercial IR camera systems have rigorous ruggedness requirements. Firefighting cameras must work in very harsh environments and are designed to survive very rough handling. Many portable thermography cameras for industrial applications are specified to survive a two-meter drop.[5] Because of the aforementioned problems with the ambiguity between cameras and cores, it is not necessarily clear these civil/commercial products are not "cores" captured by (c)(12). These civil/commercial cameras have generally not been tested against the proposed weapon shock parameters so it is not known if they would pass or fail. Numerous questions will be raised if the proposed control went into effect:

    a. Would the manufacturers of these cameras need to test their existing and/or new designs to prove they cannot survive this weapon shock specification?

    b. Who has the burden of proof and what level of testing and analysis is sufficient? What equipment is needed to do the testing?

    c. What if some units of a particular model survive and some units fail due to normal manufacturing variation?

    d. Would assuring a model doesn't pass the weapon shock test make it less rugged and potentially less competitive than competing O.U.S. models that don't face this requirement?

Additionally, this parameter would be especially troublesome in applications where ruggedness is a perceived advantage. Further, it is not necessarily clear how to ensure an IR camera reliably fails the weapon shock test but meets the ruggedness requirements of the aforementioned civil/commercial applications. Achieving this would certainly add

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[5] Some examples of rugged civil/commercial cameras that meet 2M drop, etc. are available at:

http://en-us.fluke.com/products/infrared-cameras/fluke-ti125-infrared-camera-30-hz.html

http://en-us.fluke.com/products/infrared-cameras/fluke-ti400-infrared-camera.html

http://www.flir.com/fire/content/?id=69019

http://www.bullard.com/V3/products/thermal_imaging/fire_service/

http://www.isgfire.co.uk/

https://www.scottsafety.com/en/us/Pages/ProductDetail.aspx?productdetail=Eagle+Attack+Thermal+Imaging+Camera cost and complexity to U.S. products versus O.U.S. products that don't face this requirement. Finally, at least one U.S. manufacturer has filed for patents[6] in this area, so this proposed control could even end up favoring one U.S. manufacturer versus other U.S. manufacturers.

5. In subparagraph (iii), referencing both (c)(2) and (c)(5) adds uncertainty to exactly what the "permanent encapsulation" aspect is intended to distinguish. Given that microbolometer IRFPAs must be encapsulated simply to function, any microbolometer-based "core" would always be encapsulated, so the introduction of a control parameter based on encapsulation introduces confusion. It is not clear what is being addressed with the reference to (c)(2) versus (c)(5). There are analogous issues with the other sensor types (photon detector, etc.) in subparagraphs (iv) – (xi). At minimum, it's unclear and unnecessarily complex.

6. Paragraph (c)(13) uses terms that are not clearly defined and that potentially capture civil/commercial products:

    a. Numerous handheld/portable industrial thermography cameras have a camcorder style eyepiece that, without further clarification, probably would be considered a near-to-eye display.[7] This is needed for adequate viewing while outdoors in bright sunlight conditions. It is not clear whether these systems would be considered "monoculars" or "video-based articles having a separate near-to-eye display?" There is no definition of a "video-based article?" The "near-to-eye display" term is also used in (c)(18), introducing the same uncertainties to that sub-category.

    b. Many IR cameras (and visible cameras) have connectivity options that enable them to work with commercial, off-the-shelf head-mounted display glasses (e.g. such as google glass, gaming systems, etc.), either directly or indirectly via connections with smartphones or other devices that can easily be coupled with the above commercial displays. This control needs further work to distinguish widely available commercial/consumer head-mounted display options such as the above from those used for military purposes.

7. In subparagraph (c)(16)(iii), any general-purpose IR camera could potentially be considered appropriate equipment for a "fixed-site reconnaissance, surveillance or

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[6] See US20130286215, available at https://www.google.com/patents/WO2014007888A2?cl=en&dq=infrared+thermal+imager+with+accelerometer&hl=en&sa=X&ved=0CDsQ6AEwBGoVChMIlciR6eOSxgIVikuSCh3lmwDL

[7] Some examples of Civil/Commercial IR cameras with near-to-eye display are available at:

http://en-us.fluke.com/products/infrared-cameras/tix1000-infrared-camera.html

http://www.flir.com/science/display/?id=46792

http://www.flir.com/ogi/display/?id=55671 perimeter security system." It is generally the peripheral equipment (e.g. housings, interfaces, back-end software/analytics, etc.) that distinguish such systems from commercial or industrial systems for process control, R&D, etc. Because of this, as presently written, the proposed control potentially captures any IR camera that meets the pixel/format specification—perhaps even hand-held, portable thermography cameras (e.g. if fixed-mounted on a tripod, enclosed in a housing and/or connected to line power). Further work is needed here to clarify this. As is discussed in more detail below, this subparagraph is an example of using detector format as a control parameter that, to be balanced and effective, needs a clear, objective process for periodically reviewing and adjusting the parameter as the O.U.S. availability of larger format IRFPAs inevitably advances.

8. Paragraph (c)(19) appears to be intending to control scene projector equipment that is used for hardware-in-the-loop testing of military systems; however it is overly broad as written. It should be clarified to make it clear it does not include equipment such as calibrated blackbodies that are routinely used to project radiometrically calibrated *uniform* scenes in the manufacturing and calibration processes for virtually all IR imagers and radiometric thermography cameras.

b. ***The attempt to distinguish and divide jurisdiction of packaged IRFPAs in Category XII(c) based on number of detector elements is flawed and will likely capture items that are not controlled on the Wassenaar Arrangement or are in normal commercial use***

While it is generally reasonable and accepted that systems using larger-format IRFPAs can convey some advantages for warfighters versus systems with smaller-format IRFPAs, for this to be effective as a unilateral U.S. control, it is crucial that it be set at the right level -- a level that accurately reflects what is available in the U.S. versus outside the U.S. ("O.U.S."). Further, for this to be appropriately balanced there would need to be a clear, objective process for periodically reviewing and adjusting the parameter as the O.U.S. availability of larger format IRFPAs inevitably advances. As it is, the proposed regulation offers no such review/adjustment process.

The proposed limits in (c)(3) and (c)(4) appear arbitrary and inconsistent. With appropriate scanning, a 640-1 linear array can easily be used to create a 640xN two-dimensional image. With no consideration of other factors such as frame rate, it is illogical to suggest a 129x2 pixel IRFPA conveys a significant military advantage versus a 640x1 array.

The proposed limit of 328,000 detector elements in (c)(5) is not appropriate given the significant O.U.S. availability of larger IRFPAs (e.g. 1024x768).[8] These items are in normal commercial use outside the U.S. and are not controlled on the Wassenaar Munitions lists.

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[8] See, for example, above references for ULIS and SCD.

c. ***The proposed controls for IRFPA wafers and Readout Integrated Circuits are overly broad and capture items in normal commercial use and readily available O.U.S.***

The proposed controls for IRFPA wafers and Readout Integrated Circuits ("ROICs") in subparagraphs (e)(3), (4) and (5) are overly broad and flawed for similar reasons as identified above. In particular:

1. Their wide availability from sources outside the U.S. All of the O.U.S. IRFPAs previously noted have ROICs that originate from outside the U.S. Further, there is widespread literature in the public domain about the details of ROIC design.[9]

2. Here, yet again, is another example of using detector format as a control parameter, which to be balanced and effective needs a clear, objective process for periodically reviewing and adjusting the parameter as the O.U.S. availability of larger format IRFPAs inevitably advances. Further, there is no clear reason why the control limit should be different for ROICs than for the IRFPAs associated with them (19,200 pixels versus 328,000 pixels).

3. It appears (e)(4)(iii) is intended to leave 160x120 and smaller format microbolometer ROICs to be controlled by the EAR. If that is the case, the parameter should be increased somewhat, to at least 21,000 pixels, to accommodate the extra reference and boundary rows and columns that are typically included on IRFPAs. Alternately, 32,768 might be more appropriate given the widespread use with consumer smartphones of 208x156 format IRFPAs.

4. Further, it is not clear what ROICs are captured in (e)(5) that are not already captured by (e)(4). Having multiple subparagraphs that potentially capture the same ROIC

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[9] For example, a quick search of SPIE's digital library with the terms "infrared" and "ROIC" yields 456 hits.

http://proceedings.spiedigitallibrary.org/solr/searchresults.aspx#q=infrared%20ROIC&SearchSourceType=1

A few specific examples

Turkey –

A 1280×1024-15µm CTIA ROIC for SWIR FPAs

A 640×480-17µm ROIC for uncooled microbolometer FPAs

MT3825BA: a 384×288-25µm ROIC for uncooled microbolometer FPAs

MT3250BA: a 320×256-50µm snapshot microbolometer ROIC for high-resistance detector arrays

MT6415CA: a 640×512-15µm CTIA ROIC for SWIR InGaAs detector arrays

MT6425CA: a 640 x 512-25µm CTIA ROIC for SWIR InGaAs detector arrays

(component) only serves to makes these already complex regulations even more complex and confusing.

5. Subparagraph (e)(6) is problematic on several levels. The multiple references to paragraph (c) make it confusing and unclear.

    a. A typical "vacuum package" for a microbolometer IRFPA consists of some kind of package body (typically metal or ceramic) and an IR-transparent window. Neither of these components is, by itself, a "vacuum package or sealed enclosure," so apparently neither would be controlled in this subparagraph. These components do become a "vacuum package" when sealed together and evacuated—ostensibly with an IRFPA die inside. However, once that is done, the combination of package body, window and IRFPA die is actually an encapsulated IRFPA which is already addressed in paragraph (c). So, as written, subparagraph (e)(6) either misses its mark and is a null set, or is redundant to paragraph (c).

    b. On the other hand, if one assumes that (e)(6) was intended to refer to the package body (or window), that still does not fully resolve the ambiguities. Consider, for example, a package body designed for a 320x240 microbolometer IRFPA die that is controlled in (c)(2). Whether or not the package is controlled in this subparagraph then hinges on whether it is "specially designed" for incorporation or integration *into any* article controlled in paragraphs (a), (b) or (c).

       The IRFPA die itself is controlled in (c), so following one confusing and circular—but possible—path, the classification then hinges on whether the package was "specially designed" for this IRFPA and, assuming it was, whether the package is being incorporated "into" a controlled item. If "into" is interpreted narrowly, it could be argued that the package does not get incorporated or integrated "into" the die, so therefore, the package is not controlled by this subparagraph. On the other hand, taking a slightly broader view of "into," the package is certainly integrated with the die, in which case the package would be controlled. At a minimum, the intent behind this paragraph should be clarified, or possibly it should be removed.

    c. Assuming the previous two items are addressed, another example illustrates yet another problem with this subparagraph. Consider a package body and/or window used with a 1024x768 microbolometer IRFPA. Since this IRFPA die is controlled in (c)(2) and, when packaged, it is controlled in (c)(5), it appears this package and window would be controlled by this subparagraph. However, there is a strong argument that the package for a microbolomer would not meet the "specially designed" test, because the only difference between a package for a smaller and a larger format microbolometer consists of adjustments for "fit" only.

       A package and window for a 1024x768 IRFPA are simply slightly larger versions of what would be used for smaller microbolometer IRFPAs (e.g. with fewer than 328,000 pixels). The technology and know-how needed to make them are identical, except for adjustments for "fit", as defined in connection with the

> "specially designed" release paragraph (b)(3). Indeed, a package and window developed for a 640x480 IRFPA with 25-micron pitch could potentially be used very effectively for a 1024x768 or larger IRFPA with 12-micron pitch, with adjustments only to accommodate the different size. In this case, assuming the 640x480 package was not "specially designed" for some other article in (a), (b) or (c), it would be EAR controlled while there appears to be an intent to control its 1024x768 counterpart under the ITAR. However, the "catch-and-release" provisions of the "specially designed" provisions would appear to make this category, and subparagraph (e)(6) a null set, at least with respect to microbolometers.

Paragraph (e)(10) is unclear and overly broad. Virtually any IR camera that uses an IRFPA will have some portion of its electronics that "drive," "control" and/or "image process" data from the IRFPA. Since the electrical interface of an IRFPA varies at least in details from manufacturer to manufacturer and model to model, at least some portion of the IR camera electronics is always unique for interfacing to a particular IRFPA, so there is a good chance that these items would be considered "specially designed," but it is likely that CJs would be required to clarify what is and is not controlled. Thus, as written, subparagraph (e)(10) could control at least some portion of the electronics of any IR camera that uses an IRFPA controlled in this category – even an EAR-controlled camera that has been decontrolled. It is not clear the extent to which the traditional "see-through" concept would serve to pull back an otherwise EAR camera that contains such drive, control, or image processing electronics, or whether Category XII should be interpreted more along the lines of the EAR – i.e., that classification of an end-item is done based on its characteristics, not based on incorporated controlled components.

If the see-through concept applies, in order for a civil/commercial IR camera to be EAR controlled, a manufacturer would need to identify exactly which portion of the camera electronics is "specially designed" for the IRFPA (which is not at all clear), and then make that portion tamper proof according to the Note to paragraph (e). As discussed above, how to make something sufficiently tamper proof is not at all clear. Worse still, a manufacturer would also need to determine whether the electronics that "drive," "control" and/or "image process" data from the IRFPA are "specially designed" for the IRFPA die controlled in (c)(2) or the packaged/encapsulated IRFPA controlled elsewhere in (c); e.g., in (c)(5). If anything, the electronics really has little to do with the packaging and is more logically associated with the IRFPA die controlled in (c)(2). Since (c)(2) controls practically every IRFPA the end result of the analysis could be that every IR camera would be caught up in this conundrum. In light of the apparent intent to decontrol certain types of cores and cameras, we doubt that this is what DDTC and the interagency partners intended, but greater clarification of the proper approach to classification, and the applicability of the "see-through" concept is required to avoid uncertainty and unintended consequences.

Subparagraph (e)(11)(ii) is unclear and overly broad. There is no definition of what constitutes a "target" in the explanatory note. It is not clear whether this refers to tactical "targets" associated with weapons control or aiming systems, or if it could mean "targets" such as deer, children, or other vehicles, in the context of collision avoidance systems for civilian automobiles. The use of "multi-sensor fusion" as a control criteria seems to ignore numerous examples of civil/commercial IR cameras that already include what industry would consider "multi-sensor fusion," and which have a wide range of image processing approaches for combining the imagery, not just "image blending."[10] Some examples include picture-in-picture, alpha-blending (averaging) and threshold-based algorithms applied on a pixel-by-pixel basis. In some cases a high spatial frequency filter is applied to the image data from one or more sensor (e.g. to extract edges) and then the filtered (edge) data is combined with data from the other sensor(s). It is not at all clear if all of these approaches would be considered "image blending." If not, to achieve or retain EAR control for these IR cameras, it appears a manufacturer would be left to identify and tamper proof the portions of the camera electronics that provide these functions—which has its own set of problems, as already discussed above.

Paragraph (e)(12) is also unclear and overly broad. Existing civil/commercial cameras include camcorder style eyepieces that may or may not be "near-to-eye" displays. This was already discussed in detail with respect to Paragraph (c)(13).

B. TECHNOLOGY AND DEFENSE SERVICES

Control of thermal imaging technology is a challenge under the current ITAR and EAR. Given that the CCL controlled cameras contain USML controlled IRFPAs there is already a jurisdictional split for hardware and related technology. The EAR Revisions only compound the confusion by further splitting jurisdiction. Additionally, the proposed revisions are so complicated that exporters will be forced to submit CJs in order to find the bright line.

I. The Proposed Rule Adds Complexity to Paragraph (f) and Does Not Establish a Bright Line Between the USML and CCL

The complex and interwoven notes to paragraph (f) appear to be an attempt at clarifying and distinguishing technology to *make* IRFPAs from technology needed to *use* them. This added complexity is only necessary because of the proposed structure in (c) and (e) that would keep unpackaged IRFPAs and wafers controlled under the ITAR while some packaged/encapsulated IRFPAs would be controlled under the EAR. Unfortunately, the proposed language misses its mark and only adds to lack of clarity and issues identified in (c) and (e). U.S. IRFPA manufacturers will not gain any benefit from certain IRFPAs and cores being EAR-controlled if

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[10] Some examples of civil/commercial systems with multi-sensor fusion that may go beyond mere "blending" are available at:

http://en-us.fluke.com/products/infrared-cameras/fluke-ir-fusion-technology.html

http://www.flir.com/instruments/display/?id=61194#videobox the information and software needed to use them efficiently and effectively remains ITAR controlled. It needs to be made clear that the IRFPA maker can provide a complete set of operating information for the IRFPA. Some examples of essential operating information include:

- Definition of and spec limits for all electrical I/O connections, biasing, integration, etc.
- Format and timing of input and output data/interfaces
- Definition and operation of any on-chip control or status registers
- Operating and calibration info for any on-chip non-uniformity correction and/or ambient temperature compensation functionality
- Application notes that describe how to adjust the inputs (bias and integration settings, etc.) to optimize performance (e.g. for best NETD and/or scene dynamic range) over the specified operating ambient temperature range
- Mechanical drawings and/or CAD models showing FPA location and optical center referenced to mounting datum
- Circuit simulation models (e.g. SPICE models)
- Assembly and handling requirements/limits for mounting and connection to PCA
- Performance specifications (e.g., NETD, responsivity, uniformity, scene dynamic range, pixel operability, vacuum lifetime, pixel time constant)
- FPA test and/or calibration data – e.g. output data obtained by operating FPA over range of ambient temps and scene temps

Part A of note 2 to paragraph (f) and the accompanying *"note to paragraph A of note 2 to paragraph (f)*" defines the information and data that would and would not be subject to ITAR technical data controls. In a nutshell, it is too vague regarding what is ITAR controlled and still leaves a significant gray zone (no bright line). In particular:

1. The exclusion in "Note to paragraph A of note 2 to paragraph (f)" limiting to "basic" operating instructions is vague and too narrow. Distinguishing between a "basic" operating instruction from, say, an intermediate or advanced one is completely subjective and there is no "bright line." The IRFPA user (e.g. camera developer) needs access to sufficient information to effectively use the part or it is totally useless. Instead, all operations technical data should be excluded.

2. Requiring that the information *not* include "design methodology," "engineering analysis" or "manufacturing know-how" is also too vague and limiting. While these terms are, in fact, defined in part 125.4, the definitions mostly just provide examples of information that *would* be encompassed by these terms (and thus could not be provided via EAR controls) without providing a very clear picture of what is not encompassed and *can* be provided. Worse still, "engineering analysis" specifically includes simulation and computer models—both of which are important elements for efficient and effective *use* of an IRFPA. An IRFPA user (e.g. IR camera designer) needs to understand the overall

architecture of the device and have access to, at least, a circuit simulation (e.g. SPICE) model of the IRFPA to enable efficient and effective design of an IR camera system.

3. The note addresses *technical data* but is completely silent on *defense services*. The definition of defense services includes "furnishing of assistance (including training) … in the … *testing, operation, or use* of defense articles." A U.S. IRFPA manufacturer cannot compete effectively if it cannot provide customer support and assistance on how to use or operate its IRFPAs. We recognize that DDTC has also proposed revised definitions of "defense services", but those changes are not yet implemented; additional guidance in Category XII about the exclusion of the provision of assistance with the operation of an IRFPA from the scope of Category XII(f) would provide needed clarification.

Part B of note 2 to paragraph (f) appears to be inconsistent with proposed definition changes that would remove software from the scope of "technical data" under the ITAR. See RIN 1400-AD70, revised definition of "technical data." We assume that the final Category XII controls would be adjusted in light of the proposed change to have a separate sub-category controlling software. This paragraph indicates that software that "converts" an article controlled in category XII to one subject to the EAR is still controlled under the ITAR. This is also vague and unclear. The concept of software that "*converts*" an ITAR item to an EAR item needs to be more clearly distinguished from software that is simply *used* with an ITAR item that has been incorporated into an EAR item. To hazard a guess, it seems this note may have been intended to control software that plays a role in preventing a core with an IRFPA from meeting the gunfire shock spec discussed in (c)(12)(ii), or perhaps software that otherwise downgrades an ITAR-controlled item by limiting other aspects of its performance.

However, as written it, either misses the mark for this or is so broad as to potentially capture every commercial IR camera that uses an IRFPA controlled in (c)(2). Any core that is designed to meet the gunfire shock spec will likely have software *and* hardware (e.g. accelerometer sensors and associated circuitry) involved, so it could easily be argued that the software, *by itself*, does not "convert" what would have been an ITAR-controlled core into an EAR-controlled one. On the other hand, if the software merely needs to play a role in converting the ITAR item to an EAR-controlled item, then every commercial IR camera that uses an IRFPA controlled in (c)(2) will potentially have ITAR-controlled software. (Even if the IRFPA is encapsulated and subject to EAR control, Note 1to paragraph (f) clearly indicates that tech data that directly relates to an ITAR item remains ITAR controlled, even if it could also apply to an EAR item.)

As discussed above, the technical data (and software) used to operate an IRFPA needs to have the same jurisdiction and controls as the IRFPA itself. To be competitive, U.S. IRFPA manufacturers need to be able to provide the information needed to operate the IRFPA. Often, this includes software modules and/or drivers so the IRFPA user does not need to reinvent these. Further, manufacturers of civil/commercial IR cameras cannot efficiently develop and support their products if there is ambiguity whether the camera software (including the portion that operates the IRFPA) is ITAR controlled. For larger companies with globally dispersed development teams, this creates ambiguity about what controls need to be in place among the various teams. Worse still, it potentially creates a situation where an ITAR license would be required to provide something as simple as a bug-fix software update for a civil/commercial EAR-controlled IR camera.

Part C of note 2 to paragraph (f) is also vague and overly broad. In particular:

1. As discussed above, models and tools to simulate the output of an IRFPA are basic and fundamental to designing an IR camera that uses the IRFPA. It needs to be clear that these are included in the information to operate the IRFPA.
2. Simulation of radiometrically calibrated spectral signatures and volumetric effects of plumes has numerous civil/commercial applications and would be fundamental to developing industrial and environmental gas imaging systems.

Note 3 to paragraph (f) is an additional part of the illogical attempt to draw the EAR/ITAR line for IRFPAs by distinguishing those in a "permanent encapsulated sensor assembly" from those that are not. As discussed above, this is fraught with problems and instead would create a vast gray zone and a need for countless CJs—especially for wafer-level and pixel-level packaging technologies in use with microbolometer IRFPAs.

C. EAR REVISIONS

I. Creation of new ECCNs to control items that are currently EAR99 and rollback of License Exception availability for EAR-controlled items is contrary to ECR goals

The title of the EAR Revisions states that this rule shall remove from the USML those items that the President determines no longer warrant control on the USML. To the contrary, it appears that this revision of the EAR creates new controls on items that were not previously controlled, increases licensing requirements, removes availability of license exceptions and even imposes a presumption of denial for certain items. The proposed revisions are contrary to Export Control Reform, will create an administrative burden on the civil/commercial industry, and will place U.S. companies at a competitive disadvantage.

a. Proposed Revisions to Part 740 and 742 Increase Controls and Restrict Licensing

The imposition of worldwide licensing requirements and removal of STA eligibility for 6A002, 6E001, and 6E002 items undermines the flexibility of EAR controls on commercial thermal imaging devices, and would negatively impact the competitiveness of U.S. industry by burdening its ability to work cooperatively, even internally within corporate affiliates located in the European Union and other Wassenaar Arrangement countries.

The EAR rule creates several new unilaterally controlled ECCNs, or revises unilateral ECCNs to control items that are not currently controlled, such as 0E987, 6A990, 6A994, 6E990, 6D994 and 6E994 and where the U.S. Government has provided no reasoned basis to justify why proposed worldwide Regional Stability controls are appropriate. If the U.S. Government truly believes that the need for worldwide control of such items and technologies is self-evident, then our multilateral partners must surely agree. If these items are truly highly sensitive, then it would seem to be more appropriate to propose controls for them through the Wassenaar Arrangement. If there are compelling arguments favoring worldwide control, then certainly these efforts would be successful. This makes more sense than imposing unilateral controls, and would place U.S. industry on a more level playing field, at least with respect to foreign competition in Wassenaar Arrangment countries. If our multilateral partners do not agree that controls are appropriate such items should be subject to no greater than EAR99 or AT-level control. Additionally, placing such controls on items, software and technology that are already widely available throughout the world, is illogical and will create an administrative

As with the ITAR proposed changes, key definitions are lacking, such as what criteria make an item a "weapon sight" or establishing clear criteria as to what items are "military" items to be controlled by the 600 series versus those in normal commercial use.

These changes are also inconsistent with the goals of ECR, which include facilitation of cooperation with multilateral regime partners, and not imposing new export controls on items without clear national security justification and a push for multilateral controls.

Practically speaking, these changes will dramatically increase the administrative burden of U.S. industry and BIS. Multinationals that are now employing STA to support foreign subsidiaries in R&D, manufacture and service will now have to apply for licenses that may now be denied based on the proposed presumption of denial in 742. 6(b)(iv).

b. Proposed Revisions to Section 744.9 will Impede Industry's Ability to Compete

Managing sales that are subject to Section 744.9 is already a challenge. The proposed revisions will significantly increase the complexity and burden on the U.S. thermal imaging industry. Many infrared cameras controlled by 6A993 are low-cost, consumer goods that are distributed internationally, often through multiple distributors and sometimes sold in storefronts and on-line. At the time the U.S. company sells these goods to the distributor they typically do not know the end-user or end-use. With the addition of the "is unable to determine whether" language, Fluke is uncertain if we can even continue selling these cameras via the distribution model given this proposed language.

Notwithstanding the new language, adding 6A993 to the list of items subject to 744.9 will be an overwhelming administrative/resource burden to implement proper controls. New processes, forms, training, and audits internally and with all global subs to control for this rule will be required. The increased administrative burden on distributors will hinder sales of these items, especially for 6A993.a cameras, and cause a competitive disadvantage

D. CONCLUSIONS

Overall, we conclude there are fundamental flaws in the proposed rules, which undermine the policy objectives of Export Control Reform, and the objectives of the U.S. export control regime in general.

- The proposed rules impose controls on items that are currently controlled as EAR99 and/or are in normal commercial use, expanding the extent of controls with respect to commercially available thermal imaging devices, software, and technology.

- The proposed rules are unnecessarily complex and do not establish clear lines between USML and EAR controls, lack clear definitions, or differentiate controls based on parameters that do not make sense from an industry or technical perspective. This makes the rules more difficult for companies to understand and administer internally, and does little to simplify U.S. Government enforcement efforts. The proposed changes will likely increase, rather than decrease, the need for industry and enforcement agencies to request CJ and CCATS determinations to determine what controls actually apply to night vision devices. Provisions so complicated that explanatory notes need to be explained by additional explanatory notes almost guarantee misinterpretation.

- Unjustified reductions in License Exception eligibility and the establishment of more unilateral U.S. export controls on night vision items will further reduce the ability of U.S.-based companies to work effectively with affiliates located in Wassenaar Arrangement countries, undercutting the goals of ECR to facilitate interoperability and co-development of products with regime partners. If ECR can facilitate cooperative development of major weapons systems with our allies, such as military aircraft, missiles, and warships, it should also be able to do so with respect to military thermal imaging systems, let alone with respect to EAR-controlled thermal imaging systems. Given the worldwide availability of such technology, there is no apparent justification for treating thermal imaging devices any differently in the context of ECR.

- The overall effect of these controls will likely be to reduce the competitiveness of U.S. industry, sheltering foreign competitors and enabling them to gain a greater share of the commercial and military markets. This may lead to increased costs for the U.S. government, potential loss of U.S. technological edge, and ultimately to greater U.S. government reliance on foreign-sourced thermal imaging commodities. Fastening the export control tethers too tightly, without regard to existing foreign availability and the intertwined relationship between a healthy U.S. commercial thermal imaging industry and a healthy U.S. military industry, may unintentionally transform those tethers into a noose, choking off a key source of important tactical technology for the U.S. government, while simultaneously pushing good U.S. jobs offshore to foreign competition.

Thank you once again for the opportunity to provide comments on this proposed rule. We would be pleased to discuss any of this with DDTC.

Submitted on Behalf of Fluke Corporation by,

Matthew Schmidt, Director, Business & Technology Development

Jennifer Christy, Senior Manager, Trade Compliance

Slone Pearson, International Trade Compliance Counsel

July 6, 2015

Department of Commerce
1401 Constitution Ave NW
Washington, DC 20230

Department of State
2201 C St NW
Washington, DC 20520

Dear Sirs/Madams:

We would like to thank the Department of State and the Department of Commerce for the opportunity to comment on the proposed changes to the US export controls relating to USML Category XII.

In reviewing the proposed rules, we strongly believe that fundamental changes are required in order to best serve the U.S., protecting national security by controlling sensitive technologies while supporting US participation in fast growing commercial markets for dual-use products.

We find that the proposed Category XII rules lack adequate control criteria and that such criteria do not exist and cannot be positively established. As detailed in Sections 1 and 2 below, we strongly urge that many rules be rewritten with “specially designed for military use” as the fundamental criteria to replace the proposed control criteria.

In addition, we suggest that the BIS companion rule is not necessary given that there is already a national security control for all items. The 600 series created in the companion rule should be eliminated or reintegrated into the USML as this creates an additional layer of regulation which serves no purpose other than to implement munition type controls at commerce.

Again, we thank the Department of State and the Department of Commerce for the opportunity to comment on these important changes and would welcome the chance to discuss these comments in greater detail should further clarification be required.

Respectfully submitted,

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Comments on the Proposed Changes to Export Controls for Category XII and related BIS Bookends

Contents

Overview:

We appreciate the Administration's hard work to improve US export controls. These changes are needed to increase interoperability with our NATO allies, increase transparency and fairness amongst exporters, reduce incentives to avoid US content by non-US manufacturers and to focus export control resources on articles of significant concern. For Category XII articles, it is particularly challenging because the laser and sensor technologies have critical military importance as well as significant commercial application. Extra-tight U.S. export controls have had unforeseen consequences that have disadvantaged many U.S. manufacturers in the global marketplace while strengthening foreign competitors. Export Control Reform provides the opportunity to correct these errors and right-size the rules so that they not only protect our technology but also protect the health of the industry.

In reviewing the rewritten Category XII draft, we see several fundamental flaws:

1) The proposed rules do not establish a "bright line" between USML and CCL products. The proposed rules show a line that is not only improperly position but also lacking clarity concerning the jurisdiction of the articles. Control criteria (FOMs) are given that are not well-defined and have no bearing on distinguishing military use products from dual-use products.
2) In identifying certain items as the "crown jewels" of US technology to be better protected by ITAR controls, it appears that many dual-use products have inadvertently been captured as well. While the articles may have technological importance (e.g. night vision subsystems), their dual-use nature (thermal imaging systems with commercial applications) cannot be ignored. Even if those technologies are seen as critical to US defense, the availability of the technology outside the US and the significant foreign availability of related products needs to be considered before classifying them as "crown jewels" and controlling them with restrictive munitions policies, ignoring their dual-use disposition. Otherwise, by capturing dual-use items on the USML, the US government undermines the ability of US industry to adequately participate in fast-growing international commercial markets, whereby they may leverage increased production to decrease costs and fuel further technological development. This is unilateral control and has adverse consequences.
3) In the proposed rules, the US has labeled certain articles as USML or CCL 600 Series (with ITAR-like control) even though they are controlled as dual-use items by our Wassenaar partners and classified on the Wassenaar Dual-Use List. This is inconsistent with the intended ECR goal to increase interoperability with NATO and other close allies. Without a level playing field amongst the US and its allies, US products will be avoided because of their inconsistent level of control when compared to other countries.

In the following two sections, specific comments, suggestions and requests for clarification on the proposed rules are provided. The detailed comments refer to those proposed rules that are felt to require updating. Each includes a short statement of the issue with the proposed rule's language, a discussion or reasons supporting the issue and recommendations.

Recommendations:

We strongly support export control reform relating to USML Category XII. Yet, we believe that the proposed rules require fundamental change in order best serve the U.S., protecting national security and controlling sensitive technologies while supporting US participation in fast growing commercial markets for dual-use products.

We find that the proposed Category XII rules lack adequate control criteria and that such criteria do not exist and cannot be positively enumerated. As detailed in Sections 1 and 2 below, we strongly urge that many rules be rewritten with "specially designed for military use" as the fundamental criteria to replace the proposed control criteria.

In addition, we suggest that the BIS companion rule is not necessary given that there is already a national security control for all items. The 600 series created in the companion rule should be eliminated or reintegrated into the USML as this creates an additional layer of regulation which serves no purpose other than to implement munition type controls at commerce.

Section 1: Detailed Comments to Amendment to the ITAR, Revision of USML Category XII
http://www.regulations.gov/#!documentDetail;D=DOS_FRDOC_0001-3226

Comment 1 Section: XII(a)(9)

Issue: This text could capture hands-free thermal imaging cameras which are actively being developed for firefighting applications. These hands-free thermal imaging cameras have been available in the past. For example, FireFLIR, a product introduced by FLIR, and a helmet-mounted device by Cairns. Newer models are expected to have infrared cameras mounted to the helmet with the HMD attached to the breathing apparatus.

Recommendation: Revise the proposed rule to: "Helmet mounted display (HMD) systems or equipment *specially designed for military use*, incorporating optical sights or slewing devices, which include the ability to aim, launch, track, or manage munitions, or control infrared imaging systems or equipment, other than such items controlled in Category VIII, (e.g., Combat Vehicle Crew HMD, Mounted Warrior HMD, Integrated Helmet Assembly Subsystem, Drivers Head Tracked Vision System)."

Comment 2 Section: XII(c)

Issue: The section (c) title is confusing. "Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:". It includes physical items (e.g. "image intensifier tubes"), applications (e.g. "night vision") and generic classifications (e.g. "electro-optic"?).

Recommendation: Choose a more generic category title that is clear and balanced.

Comment 3 Section: XII(c)(2)

Issue: Should the rules separately consider packaged and unpackaged IRFPAs?

Discussion: Regarding the separate consideration of packaged and unpackaged IRFPAs, there does not appear to be a large market today for unpackaged IRFPAs. So, the point seems rather moot. In addition, I believe a clarification is required for devices that incorporate the package in the detector manufacturing process, such as wafer-level-packaging and pixel-level-packaging. With the motivation to build smaller devices with lower cost, innovative technologies will likely be introduced and so the distinction needs to be clarified.

Recommendation: Modify the text to clarify how devices are controlled when the packaging is incorporated into the IRFPA.

Comment 4 Section: XII(c)(3)

Issue: The number of detector elements is not a criteria that delineates dual-use and military use encapsulated one-dimensional photon detector IRFPAs.

Reasons:

1) The detector is a dual-use device. Common commercial applications include: dense wavelength division multiplexing (DWDM), remote sensing (vegetation, clouds, humidity, atmospheric conditions), wild fires, radiometry.
2) The pixel count constraint has no specific military significance.
3) These are listed on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Xenics Xlin-17-3000 (http://www.xenics.com/en/xlin-17-3000)

   b. Hamamatsu (http://www.hamamatsu.com/jp/en/product/category/3100/4005/4208/4121/index.html)

Recommendation: Revise the proposed rule to: "One-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly~~, having greater than 640 detector elements~~ *and specially designed for military use;*"

Comment 5 Section: XII(c)(4)

Issue: The number of detector elements is not a criteria that delineates dual-use and military use encapsulated two-dimensional photon detector IRFPAs.

Reasons:

1) The detector is a dual-use device.
2) The pixel count constraint has no specific military significance.
3) These are listed on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
   a. Xenics XFPA-1.7-640-LN2 (http://www.xenics.com/en/xfpa-17-640-ln2)
   b. Hamamatsu (http://www.hamamatsu.com/jp/en/product/category/3100/4005/4208/4121/index.html)
   c. Chunghwa Telecom (http://www.leadinglight.com.tw/images/Large%20format%20FPA%20spec.pdf)
   d. SCD (http://www.scd.co.il/SCD/Templates/showpage.asp?DBID=1&LNGID=1&TMID=108&FID=1287&IID=1682)

Recommendation: Revise the proposed rule to: "Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly~~, having greater than 256 detector elements~~ *and specially designed for military use*;"

Comment 6 Section: XII(c)(5)

Issue: The use of array size to identify those encapsulated microbolometer IRFPAs that are for military use is not appropriate. Encapsulated microbolometer IRFPAs having more than 328,000 detector elements are dual-use and commonly used in commercial applications.

Reasons:

1) The detectors are dual-use devices. Commercial applications include: commercial automotive vision, UAVs, security, thermography, scientific research.
2) Constraining the array size has no specific military significance.
3) These are listed on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
   a. ULIS PICO-1024 (http://www.ulis-ir.com/index.php?infrared-detector=gen2pico1024)
   b. SCD Bird-XGA (http://www.scd.co.il/Bird-XGA-17)

Recommendation: Revise the proposed rule to: "Microbolometer IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly~~, having greater than 328,000 detector elements~~ *and specially designed for military use*;".

Comment 7 Section: XII(c)(7)

Issue: The use of an array dimension to identify those charge multiplication FPAs that are for military use is not appropriate or consistent with their use. Charge multiplication FPAs having greater than 1,600 elements are commonly used in commercial applications and must be treated as dual-use.

Reasons:

1) The detectors are dual-use devices. Commercial applications include: enhanced underwater imaging, life science imaging applications (such as single molecule detection, live cell fluorescence microscopy, ion signaling and weak luminescence detection), photon counting, adaptive optics, single molecule detection, neutron tomography, Raman detection.
2) Constraining the array dimension has no specific military significance.

Recommendation: Revise the proposed rule to: "(7) Charge multiplication focal plane arrays ~~having greater than 1,600 elements in any dimension and having a maximum radiant sensitivity exceeding 50 mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, and avalanche detector elements therefor;~~ *specially designed for military use*;".

Comment 8 Section: XII(c)(8)

Issue: Encapsulated charge multiplication FPAs are dual-use devices commonly used in commercial applications.

Reasons:

1) The detectors are dual-use devices. Commercial applications include: enhanced underwater imaging, life science imaging applications (such as single molecule detection, live cell fluorescence microscopy, ion signaling and weak luminescence detection), photon counting, adaptive optics, single molecule detection, neutron tomography, Raman detection.
2) These are listed on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

Recommendation: Revise the proposed rule to: "(8) Charge multiplication focal plane arrays described in paragraph (c)(7) of this category in a permanent encapsulated sensor assembly, ~~and avalanche detector elements therefor;~~ *and specially designed for military use*;".

Comment 9 Section: XII(c)(9)

Issues: This section does not adequately capture only the IDCA-based IRFPA detectors that are designed for military use.

Reasons:

1) Some cooled IDCA-based IRFPA detectors that are specially designed for dual-use products would be captured by this rule. For example, those detectors that are designed for use in the following gas imaging cameras are designed exclusively for dual-use products and are inadvertently captured by this rule:
    a. IR Cameras Niatros (http://www.ircameras.com/camera/niatros-optical-gas-imager/)
    b. FLIR Gas FindIR (http://www.flir.com/ogi/display/?id=55671)
    c. Opgal Eye-C-Gas (http://www.opgal.com/portals/0/pdf/eyecgas_27.11.2012_small.pdf)
2) The following criteria are not related to the military use of this technology:
    a. cooling source temperatures below 218K
    b. mean-time-to-failure (MTTF) in excess of 3000 hours
    c. "active cold fingers" (Note: The term "active cold finger" is not common terminology and seems to be used only in export control papers. I believe that the meaning here is to

identify those cold fingers that are not passively cooled with liquid nitrogen or compressed gases. It may be better in the future to specific "non-passively cooled".)

3) Some cooled IDCA-based IRFPA detectors are listed on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

Recommendation: Revise the proposed rule to:

"(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

(i) Variable or dual aperture mechanisms; or

(ii) Dewars specially designed for military use;"

<u>Comment 10</u> <u>Section: XII(c)(12)</u>

Issue: The listing of "Infrared imaging camera cores" in the title is confusing, is too broad in scope and includes terms that can be interpreted in different ways.

Reason:

1) This section includes more than just cores with infrared detectors. For example, the first option lists an image intensifier tube as a possible component, yet image intensifier tubes are not components of "Infrared imaging camera cores".
2) In order to prevent capturing many dual-use products, the title needs to be limited to constraint products specially designed for military use.
3) The title lists "electronics and optics" without being very specific about the nature of those items. For example, were they designed for military use only?

Recommendation: Revise the header for section (12) to: "(12) ~~Infrared i~~Imaging camera cores (*e.g.,* modules, engines, kits)~~, and specially designed~~ ~~electronics and optics~~ *specially designed for military use and* ~~,~~having any of the following:". Move optics, electronics and accessories to Xii(e).

<u>Comment 11</u> <u>Section: XII(c)(12)(i)</u>

Issue: This rule inadvertently captures dual-use intensified cameras that are designed for commercial applications such as scientific imaging.

Reasons:

1) The cameras are dual-use devices. The commercial applications for this intensified cameras include: fluorescence lifetime imaging microscopy, time-resolved imaging & spectroscopy, plasma diagnostics, combustion, planar laser induced fluorescence and particle imaging velocimetry.
2) Imposing military-level export controls on a dual-use camera is not justified simply because it contains an image intensifier tube.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Andor iStar 512T (http://www.andor.com/scientific-cameras/intensified-camera-series)
    b. Photonic Science (http://www.photonic-science.co.uk/products/intensified-ccd-cameras.html)
    c. LaVision Nanostar (http://www.lavision.de/en/products/cameras/iccd_cameras.php)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(i) An image intensifier tube ~~described in paragraph (c)(1) of this~~;".

Comment 12 Section: XII(c)(12)(ii)

Issue: The shock criteria listed are poorly defined and are not exclusive to military products. This rule inadvertently captures dual-use microbolometer cameras.

Reasons:

1) The definition for maximum shock is not sufficient to fully define the constraint. For example, what is meant by "Output imagery"? Can the image flicker? How much? How can the 325 g of force be applied? What is the permissible shock profile?
2) Many commercial applications require dual-use microbolometer cameras to sustain shock. For example, some are used in an industrial setting and must withstand a 6' drop from a ladder. In a firefighting application, the thermal imager is used by the firefighter in very harsh conditions.
3) Constraining a camera based on the fact that it withstands a briefly defined shock rating is not sufficient to justify military significance.
4) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

Recommendation: Remove the proposed rule XII(c)(12)(ii).

Comment 13 Section: XII(c)(12)(iii)

Issue: The number of detector elements is not a criteria that delineates dual-use and military use microbolometer IRFPAs.

Reasons:

1) There are dual-use cameras that are captured by this rule. Applications for dual-use cameras include: portable thermography, industrial and scientific R&D, predictive and preventive maintenance, building inspection.
2) Constraining the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Jenoptik IR-TCM-HD-1024 Thermography Camera Module (http://www.jenoptik.com/en-ir-tcm-hd-1024)
    b. Jenoptik VarioCAM HD Thermography Camera (http://www.jenoptik.com/en-variocam-high-definition-thermography-camera)
    c. Thermoteknix MicroCAM 1024 Thermal Imager (http://www.thermoteknix.com/products/oem-thermal-imaging/microcam-1024hd-thermal-imager/)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(iii) A microbolometer IRFPA;". If the products are limited to military use items only, no criteria limiting performance of the microbolometers used need to be stated.

Comment 14 Section: XII(c)(12)(iv)

Issue: This rule inadvertently captures some dual-use camera cores that use IDCAs.

Reasons:

1) There are dual-use cooled cameras that are captured by this rule. Applications for dual-use cooled cameras include: gas imaging, hyperspectral imaging, spectroscopy.
2) Constraining the camera simply because it uses a cryocooled IDCA has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Opgal Eye-C-Gas (http://www.opgal.com/portals/0/pdf/eyecgas_27.11.2012_small.pdf)
    b. Telops Hyper-Cam Methane (http://www.telops.com/en/hyperspectral-cameras/hyper-cam-methane)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(iv) An IDCA or IDCA parts or components described in paragraph (e)(7);". If the products are limited to military use items only, no criteria limiting performance of the IDCAs used need to be stated.

Comment 15 Section: XII(c)(12)(v)

Issue: This rule lists unencapsulated one-dimensional photon detector IRFPAs.

Reasons:

1) I'm not familiar with any product that uses an unencapsulated detector without first encapsulating it.

Recommendation: Seems like an unnecessary addition.

Comment 16 Section: XII(c)(12)(vi)

Issue: This rule lists unencapsulated two-dimensional photon detector IRFPAs.

Reasons:

1) I'm not familiar with any product that uses an unencapsulated detector without first encapsulating it.

Recommendation: Seems like an unnecessary addition.

Comment 17 Section: XII(c)(12)(vii)

Issue: This rule inadvertently captures some dual-use camera cores that use one-dimensional photon detector IRFPAs.

Reasons:

1) There are dual-use infrared linescan cameras that are captured by this rule. Applications for linescan cameras include: portable thermography, industrial and scientific R&D, predictive and preventive maintenance, building inspection. Here are some examples of dual-use cameras that are captured by the rule:
    a. Sensors Unlimited (http://www.sensorsinc.com/products/linescan-cameras/)
2) Constraining products based on the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Xenics Lynx-1024-CL (http://www.xenics.com/en/camera/lynx-1024-cl)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(vii) A one-dimensional photon detector IRFPA;". If the products are limited to military use items only, no criteria limiting performance need to be stated.

<u>Comment 18</u> <u>Section: XII(c)(12)(viii)</u>

Issue: This rule inadvertently captures some dual-use camera InGaAs cores that use two-dimensional photon detector IRFPAs.

Reasons:

1) There are dual-use infrared InGaAs cameras that are captured by this rule. Applications for dual-use InGaAs cameras include: spectroscopy, semiconductor inspection and DWDM optical performance monitoring. Here are some examples of dual-use cameras that are captured by the rule:
    a. Sensors Unlimited Mini SWIR (http://www.sensorsinc.com/products/detail/mini-swir-jsx-snapshot-camera-60-fps)
    b. FLIR Tau SWIR (http://www.flir.com/cores/display/?id=51890)
2) Constraining products based on the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.
4) There are foreign available dual-use products, for example:
    a. Xenics BobCat 640 (http://www.xenics.com/en/bobcat-640-gige)
    b. Raptor Owl 640 (http://www.raptorphotonics.com/product/owl-640-analog-33)
    c. SCD InGaAs 640 (http://www.scdusa-ir.com/ingaas/)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(viii) A two-dimensional photon detector IRFPA ~~described in paragraph (c)(2) or (4) of this category~~ having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm~~, and greater than 111,000 detector elements~~;". If the products are limited to military use items only, no criteria limiting performance need to be stated.

<u>Comment 19</u> <u>Section: XII(c)(12)(ix)</u>

Issue: This rule inadvertently captures some dual-use camera cooled cores that use two-dimensional cooled IDCAs.

Reasons:

1) There are dual-use infrared research cameras and certain gas-imaging that are captured by this rule. Applications for infrared research cameras include: Non-destructive testing, high-speed imaging of dynamic events, gaseous cloud studies. Applications for gas-imaging cameras include: methane emissions monitoring, leak detection, pollution monitoring, flare measurement, standoff emission characterization of smokestacks. Here are some examples of dual-use cameras that are captured by the rule:
    a. FLIR GF300/320 Infrared Cameras (http://www.flir.com/ogi/display/?id=55671)
    b. Sofradir EC IRE-320M Camera (http://www.thermal-cameras.com/th-mwirs.html)
2) Constraining products based on the pixel count has no specific military significance.
3) As with other dual-use items, these items are controlled on the Wassenaar "Sensitive List of Dual-Use Goods and Technologies" and not on the Wassenaar "Munitions List". Listing dual-use items on the USML will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

4) There are foreign available dual-use products, for example:
   a. Xenics Onca-LWIR-MCT-384 (http://www.xenics.com/en/onca-lwir-mct-384)
   b. Telops TX-IR (http://www.telops.com/en/infrared-cameras/ts-ir-thermal-scientific-ir-camera)

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(ix) A two-dimensional photon detector IRFPA ~~described in paragraph (c)(4) of this category~~ having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm;". If the products are limited to military use items only, no criteria limiting performance need to be stated.

Comment 20 Section: XII(c)(12)(xi)
Issue: The term "IRFPA" should be excluded from this description.
Reasons: The FPAs mentioned in XII(c)(7) and XII(c)(8) are not IRFPAs.
Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "A charge multiplication FPA controlled in paragraph (c)(7) or (c)(8) of this category".

Comment 21 Section: XII(c)(13)(ii)
Issue: This rule inadvertently controls firefighting cameras and thermography cameras.
Reasons:
Recommendation:

Comment 22 Section: XII(c)(14)(iii)
Issue: This rule captures large format perimeter security cameras and their optics which are dual-use articles.
Reasons:
   a. Large format cameras are often used to monitor wide areas and so controlling them here is ineffective.
   b. In addition, multiple cameras would accomplish the same function as one high definition camera.

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(iii) Fixed-site reconnaissance, surveillance or perimeter security systems or equipment *specially designed for military use* ~~having greater than 640 detector elements in any dimension~~;".

Comment 23 Section: XII(c)(14)(iv)
Issue: This rule captures large format perimeter security cameras with zoom optics which are dual-use articles.
Reasons:
   a. Large format cameras are often used to monitor wide areas and so controlling them here is ineffective.
   b. In addition, multiple cameras would accomplish the same function as one high definition camera.

Recommendation: Revise the header of section (12) to consider only products "specially designed for military use" and revise the proposed rule to: "(iv) Combat vehicle, tactical wheeled vehicle, naval vessel, or aircraft pilotage systems or equipment *specially designed for military use and* having a variable field of view or field of regard (*e.g.,* electronic pan or tilt), and either an IRFPA article controlled in this subchapter with greater than 640 detector elements in any dimension, or an IIT controlled in this category (*e.g.,* DAS, DVE, SeaFLIR, PNVS);".

Comment 24 Section: XII(c)(16)

Issue: Seeks to control as ITAR any optics that are designed for high definition infrared cameras [section XII(c)(16)(iii)] and high definition infrared cameras with zoom lenses [section XII(c)(16)(iv)].

Reasons: Infrared optics are normally designed for diverse commercial applications. Optics designed for military use normally have additional requirements. It is inadvisable to control all these infrared optics on the USML if they are designed for less stringent commercial applications.

Recommendation: Control only those infrared optics that were designed for military use.

Comment 25 Section: XII(c)(18)

Issue: Seems that these near-to-eye display are accessory items adequately covered in XII(e)(12).

Reasons:

Recommendation: Remove this rule.

Comment 26 Section: XII(c) Note 1 to paragraph (c)

Issue: Though unrealistic, the requirement “A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) prevents … without destruction or damage to the IRFPA” is one that, with enough expense and motivation, may be able to be overcome. As such, the distinction between an unencapsulated and encapsulated sensor assembly may be irrelevant even though impractical. If the motivation to control unencapsulated IRFPAs is to more easily control the technology behind the IRFPA, it seems unnecessary to have such a demanding constraint. In addition, this constraint does not exist for dual-use non-US IRFPAs, so why should US manufacturers be encumbered with the cost and development of tamper resistant methods when we have agreed that our Wassenaar partners do not have the same requirement?

Recommendation: Remove Note 1 to paragraph (c).

Comment 27 Section: XII(c) Note 2 to paragraph (c)

Issue:

1) This note does not create a “bright line” between circumstances that meet the requirement and those that do not.
2) The parameter “having greater than 640 detector elements in any dimension” is not exclusive to military use.
3) Image intensifiers do not necessarily have “pixels”, so including (c)(1) is incorrect.
4) The requirement that the items “… cannot be removed without destruction or damage to the article or render the item inoperable” does not define “damage” or “inoperable”. For example, if the article’s paint is scratched, is it damaged? If so, then it’s a trivial requirement.
5) Why is there a constraint on removal of the item when most of these IRFPAs are available from foreign sources?
6) It is not practical to have such a requirement for products sold commercially as service and repair will be very costly. Implementing in accordance with this rule will make US companies uncompetitive and will encourage using non-US devices by foreign end-customers.
7) It may be possible but impractical to remove the item without destruction or damage.
8) These constraints are not placed on items listed on the Wassenaar Dual-Use List and consequently result in unilateral control of US-made devices which is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

Recommendation: Dual-use end products need to be controlled as dual-use. However, distribution of articles that contain munitions items need to be export controlled and acceptance should demand certain evaluation of the end-customer and security of the article. Remove Note 2 to paragraph (c).

Comment 28 Section: XII(e)(7)

Issue: "Cryocoolers having a cooling source temperature below 218K and a mean-time-to-failure (MTTF) in excess of 3000 hours" pertains to dual-use items and should not be controlled in this section unless they are specially designed for military use.

Reasons: Foreign availability for cryocoolers used in various civil applications. For example:

1) Ricor K508 (MTTF 10,000 hours): http://www.ricor.com/products/integral-rotary/k508/

Recommendation: Use specially designed for military use to capture any uniquely military cryocoolers.

Comment 29 Section: XII(e)(9)

Issue: "Infrared lenses, mirrors, …" are normally dual-use items and should not be controlled in this section unless they are specially designed for military use.

Reasons: Foreign availability of IR optics within and outside of Wassenaar

1) Z&Z Optic, China: http://www.zzoptic.com/
2) Ophir Optics, Israel: http://www.ophiropt.com/
3) Wavelength Tech, Singapore: http://www.wavelength-tech.com/

Recommendation: Use specially designed for military use to capture any uniquely military optics and remove from the companion rule references to 6A615 which impose unilateral controls on US suppliers.

Comment 30 Section: XII(e)(11)(ii)

Issue: Fusion is useful in dual-use articles. Check that items are not controlled in this section unless they are specially designed for military use. Also, be more specific about which sensors are being fused (e.g. visible and IR)?

Reasons: Foreign availability of fusion algorithms and systems. For example:

1) Xenics, http://www.xenics.com/en/meerkat-fusion

Recommendation: Use specially designed for military use to capture any uniquely military algorithm or electronics fusion approaches. The statement "to improve classification, identification, or tracking of targets relative to any of the individual sensors is too broad.

Section 2: Detailed Comments to Amendment to the EAR, Revisions resulting from Category XII changes

http://www.regulations.gov/#!documentDetail;D=BIS-2015-0016-0001

Comment 1 Section: 740.16 Availability of License Exemption APR

Issue: Cameras described in ECCN 6A003 may only be exported or re-exported under License Exception APR if they have no more than 111,000 elements (among other factors). It makes no sense to inflict the limitation on the number of elements when the articles are embedded in civil products.

Reasons:

1) Such a constraint could adversely impact civil applications that require additional array size.
2) Multiple lower resolution cameras positioned together could achieve the same performance. Consequently, the limitation has no real performance impact.
3) These items are controlled freely on the Wassenaar Dual-Use List. Encumbering US products will result in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices.

Recommendation: Remove the pixel count constraint entirely.

Comment 2 Section: 744.0 Revision to require a license for 9 Hz cameras

Issue: Apparently 744.9 is to be revised to require a license for 9 Hz cameras if exported to a "military end user" or if incorporated into a "military commodity".

Reasons: If the article wasn't designed specifically for military use, then this seems to establish a control requirement that is inappropriate. While the article may have military applicability, because of significant commercial use, the item is essentially commoditized. Encumbering US manufacturers would impose restrictions that are neither fair nor are easily managed.

Recommendation: Maintain the sanctity of <9Hz camera cores.

Comment 3 Section: ECCN 6A615c

Issue: The section ECCN 6A615c seeks to control "certain zinc selenide, zinc sulfide, germanium, or chalcogenide optics blanks." Though it's not clear, it seems likely (and should be clarified) that this rule also controls the lenses that are made from the blanks. This is absurd as many of the infrared lenses are designed for non-military applications.

Reasons: Encumbering US lens manufacturers with these export controls will undermine their participation in US markets. Significant foreign availability exists for infrared lenses outside the US (including Israel, Germany, China, The Netherlands and Japan) and would certainly fulfil the market need.

Recommendation: Control only those lenses that were designed for military use or use materials (such as AMTIR4) that may only be used in military applications.

Comment 4 Section: ECCN 6A615g

Issue: The section ECCN 6A615g section g captures IR zoom lenses used on cooled cameras ("…equipment incorporating a variable field of view or field of regard, and incorporating a photon detector-based infrared focal plane array having less than 640 elements"). Many infrared lenses are designed for non-military applications.

Reasons: Encumbering US lens manufacturers with the same export controls for both military and commercial products when significant foreign availability exists is not appropriate.

Recommendation: Control only those lenses that were designed for military use or use materials (such as AMTIR4) that may only be used in military applications.

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Subject: Fraser Optics Response to Category XII Proposed Changes

1. Switching from Figure of Merit (FOM) to "luminous sensitivity" as *the* discriminating factor is seen as an arbitrary and confusing value versus the current method (signal-to-noise ratio x resolution).What is the comparison of luminous sensitivity to established FOM levels so we can assess the impacts. Fraser is intimately involved with providing IITs thru export licensing and this change could rewrite all the licensing precedents established up to now for years of exporting internationally.
    a. Why the change at all. IITs are 30 year old technology and are available all over the world. This will make it harder to sell our systems outfitted with IITs internationally by changing from FOM to this unknown value and give openings to cut into our sales with tubes more easily available with less hassles and controls. We open the door for European companies and others like Photonis, 4 Russian manufacturers and a German company. We already see sales internationally turning from US manufactured IITs to European due to export controls and fluidity of approvals by the US.
    b. Microamps per lumen
        i. How does this transfer to FOM levels as currently used
        ii. Why the change?
        iii. What is the purpose - harden the controls on old technology
    c. Is auto-gating a part of the licensing process still, or are there levels of auto-gating?

2. Why should 9 Hz Thermal imaging cameras already cleared for commercial use by Commodity Jurisdictions be subject to export-control regardless of their integration into foreign equipment? This is counter-productive to the stated goal of US products being included in foreign design and ultimately detrimental to U.S exports.
    a. 9 Hz thermal imaging cameras are available globally and can replace US manufactured devices tied up in added controls and licensing not there previously. Any effect on acquisition by foreign countries will be minimal at best and ensure that U.S companies are written out of foreign military designs
        i. EU Annex I List of Dual Use Items and Technology (6A003.b.4.b)
    b. At our company, one that employs less than 35 people, this could seriously hamper our ability to close millions of dollars worth of sales with this attempt to keep 20 year old technology out of the hands of the wrong people but instead negatively impact the sales and growth of US companies thru export and Commodity Jurisdiction sales currently underway or in business plans for 2016 and out.
3. What capabilities of a thermal sensor array are changed when it is taken out of its "encapsulated sensor assembly?" Whether it is a permanent assembly or not has no affect on the capabilities of the imager.
4. What does the category encapsulated sensor Assembly for a thermal imager mean, what is the purpose of this description???
    a. Applying software to change the capabilities is completely different and already covered.
    b. The logic of this proposal is: (non-ITAR product)+(non-ITAR product) = ITAR product
    c. This is exactly the kind of change that will stifle exports while offering nothing in the way of protecting US technologies, forces, or security interests.
5. If a product is already designated non-ITAR, then why is it assumed:
    a. That restricting its sale is making any measurable impact on foreign forces ability to acquire it?
    b. That restricting its sale is good for the US and for US companies
    c. How are US companies expected to operate in this severely limited environment???

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d. That other countries aren't taking advantage of this and pushing their technology and products into areas where US companies dominate?
e. That we aren't *already* being excluded from foreign innovation, design, and exports?
f. That we won't miss out on incorporating new technologies to improve our own?
g. That billions of dollars won't be lost in exports every year?
h. That this won't cost thousands of jobs?

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May 1, 2015

SUBMITTED VIA EMAIL TO: DDTCPUBLICCOMMENTS@STATE.GOV

Mr. C. Edward Peartree
Director
Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, D.C. 20037

RE: Request for Comments Regarding Review of Categories VIII and XIX (80 FR 11314, dated March 2, 2015)

Dear Mr. Peartree:

On behalf of Garmin International, Inc. ("Garmin"), we are pleased to provide these comments responding to the Request for Comments Regarding Review of U.S. Munitions List ("USML") Categories VIII and XIX, administered by the Directorate of Defense Trade Controls ("DDTC").

Garmin believes that Category VIII(e) has operated well. We believe that Category XII should not be amended to provide an enumerated clause that describes gyros, AHRS, or INS that operate at defined performance parameters. The catch and release provisions for gyroscopes, AHRS, and INS better achieve the goals of Export Controls Reform to exclude from the USML items in normal commercial use over time.

Catch and Release Provisions of VIII(e)

We appreciate the strategy of DDTC periodically to review Category VIII, and Garmin understands the general preference of DDTC and the Administration to use enumerated performance criteria where possible. However, there are reasons this policy-making strategy is not the better alternative when compared to the catch and release provisions of Category VIII(e). In anticipation of publication of a revised Category XII, Garmin is gathering information regarding common commercial use of gyroscopes, AHRS, and INS equipment and will comment further on Category XII when it is published.

Recommendation

Garmin believes AHRS, INS, and gyros should remain subject only to a catch-all clause under the USML. Category XII should not be amended to provide an enumerated clause that describes gyroscopes, AHRS, or INS that operate at defined performance parameters. The catch and release provisions better achieve the goals of Export Controls Reform to exclude from the USML items in normal commercial use over time. Commercial avionics has and will continue to evolve quickly to improve safety and efficiency of commercial flight.

Sincerely,

John Preis
Manager, International Trade Compliance

PUBLIC SUBMISSION

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General Comment

I am Gary Strahan CEO of "ICI Infrared Cameras Inc. I am an Honorably Discharged Navy Veteran, Father, Grandfather and small business owner.This 125 Page Confusing Dissertation will honestly likely be the End of my company which has been in business for 20 years. This ITAR change proposal will hinder my companies growth and Export capability. We are growing and currently hiring people here in the U.S.A and creating Jobs here in the U.S.A and I will likely have to hire a $500 per hour attorney if this proposal becomes law just to make sure I stay out of jail before I ship a system outside the U.S.. " For Example" Things are bad enough now as a company in Mexico or South America can buy an excellent 640 x 480 camera from China that operates at 30 Hz or 60 Hz and sell it a few hundred miles form my home with NO ISSUE while I am relegated to selling a 9 Hz camera. This is ridiculous!This 125 pages will discourage us from growing and exporting. Why is this necessary given the foreign availability and how US companies purchase and rebrand/label products using foreign (i.e. PRC, French) fpas. If these foreign cameras/fpas are that bad, why does the US military use French cameras/fpas in the US KC-46 refueling tanker, clip-ons, IRST programs. No ITAR issues for the PRC, EU, etc. So should anything uncooled be on the ITAR unless it meets specific military parameters which are not found in the rewrite. Why doesn't our Government just make all Uncooled sensors Commerce? I will be speaking to whoever will listen in Congress and including the Governors in all of the states I currently do business in Including Texas, Michigan, and Minnesota and Lord knows Michigan needs all the help it can get . The U.S. Needs all the jobs it can get and this proposal does nothing but hinder it.This USML rule is Poor and should be thrown out. Start over Please!!! The foreign availability of these systems is

everywhere I have uploaded brochures that meet the "performance" metrics in Cat 12. Does PRC make cores that withstand 325g at .43 mS shock ? Is that even a good metric or can it result in a unlevel playing field for US exporters (some say they meet it, some say they don't) ? The definition of a Core or hermetically sealed FPA is Not even defined in this document. Do we even know what a core is ? You may think you do but does industry agree with you or is this just another situation where you will call me and ask how Company X is selling their "camera" while you can't ? What is permanently encapsulated mean ? Will this result in more CJ submissions ? Is this a bright line or worse ? It is absolutely more WORSE and will likely put ICI out of business so even more US jobs gone to Foreign Competition! Should the entire effort be ditched in favor of something more simple and enforceable - YES!!! perhaps the Wassenaar Munitions List or simply just changing the word in the existing Cat 12 from "specifically" designed to "specially" designed ? Help Please my company. Many who see this document will not even comment as it is 125 pages and more than any reasonable working man has time to read. Please make it Simple and Help small U.S. Businesses like mine grow and create jobs. I love this country and when bad guys try and get systems I report them. I report them. I guess the Government just wants me to denounce my U.S. Citizenship move out of MY Country and start selling Chinese cameras. Please stop this madness and help small companies like mine grow and prosper. We use these sensors to make Medical Devices to help save lives. Inspect Electrical and Mechanical systems to help prevent explosions. help Firefighters see through h smoke.
Please cut the red tape and really consider what you are doing to small companies like mine. Thank you Gary E. Strahan CEO Infrared Cameras Inc. "ICI"

Please visit Dali Infrared, Wuhan Guide, SAT Infrared and really find out what is available. Please help ease these export regulations so we at least have a chance to compete

From:	Gary Strahan
To:	DDTCPublicComments
Subject:	Jobs and New ITAR Rule
Date:	Friday, June 05, 2015 5:35:13 PM
Attachments:	image002.png

USML Export Control Form Category VII

If the new is passed it will crush my company, again. Is our Government and DOD really trying to help my company?

I have been watching Foreign Infrared Sensor and Camera manufacturers that did not exist 5-20 years ago grow and triple and quadruple in size. Companies around the world grow and expand and yet we still have our hands tied. Companies like Flir who I used to work for just buy foreign companies and circumvent our government tying their hands. Flir is in fact the largest purchaser of Ulis(French) Sensors in the world. Ulis business has Exploded over the last 10 years because our governments export restrictions. Flir has deep pockets and was able to buy Cedip in France in order to circumvent U.S. Export Law. We do not that capability. Here are a few of these companies who now manufacture sensors and cameras that are growing and some did not even exist 10 years ago.

http://redirect.state.sbu/?url=http://www.gwic.com.cn/en_corpIntro.html
http://redirect.state.sbu/?url=http://www.dali-tech.us/
http://redirect.state.sbu/?url=http://www.ulis-ir.com/
http://redirect.state.sbu/?url=http://www.satir-uk.com/
http://redirect.state.sbu/?url=http://www.wuhan-guide.com/en/

20 years ago most of these companies were not even around. If we had not restricted sensor and camera sales I will bet my company would be at least 5 times the size that it is now

What does that mean. **It means JOBS for U. S. Citizens**. It means we have even more leadership in the world market. **It means health for our country and a better Tax Base.**

Do our Senators, Congressman, Governors, or Representatives really care. The reality is they do not really understand the technology or the potential of the technology. It is like they have the Inventors of the Computer or Smart Phone or Digital camera in front of them and they do not even realize it. I am an Honorably Discharged Veteran and I do not believe the U.S.DOD cares if my business survives or fails. We will likely watch what happened to the Satellite Industry happen to the Infrared Industry. We used to own the night and 95% of the market and now we are at 50% if things do not open up and change in the next 5 years I will bet we go to 20%

Gary Strahan
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From:	Gary Strahan
To:	DDTCPublicComments
Cc:	"Jennifer LeBlanc"; David@ici1.com; joe@ici1.com
Subject:	ITAR Amendment Category VII
Date:	Thursday, May 28, 2015 5:40:15 PM
Attachments:	image002.png

To whom it may concern,

I care and this amendment impacts ICI and all of its employees. This Proposal was supposed to make things easier and it really is headed in the wrong direction. It needs to be simple and fundamentally rewritten. We believe "Specially Designed" should be fully applied to this Category as opposed to Performance Parameters. We all believe the USML should align with the Wassenaar Arrangement Munitions list.

We all know the DOD does not want to discuss "Foreign Availability" but it is a Reality. A reality that is allowing Foreign Suppliers to Expand and grow while many U.S. Commercial companies have shrunk, gone bankrupt, or out of business. We are trying to grow and create jobs here in the U.S. but frankly we are being regulated and taxed to death. Please take a look at the links below. These guys are making some excellent sensors. We need to be creating U.S. jobs and helping U.S. companies. The fact is I cannot ship a 30 Hz 640 x 480 camera to Mexico Ford Motor Company 300 miles from my home but Dali in China can overnight them one. I sincerely believe if we do not do something about this ICI will be out of business. Help!

http://redirect.state.sbu/?url=http://www.gwic.com.cn/en_corpIntro.html

http://redirect.state.sbu/?url=http://www.dali-tech.us/

http://redirect.state.sbu/?url=http://www.diytrade.com/china/pl/0-k-c-1/thermal_camera.html

Best regards,

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GAS IMAGING TECHNOLOGY, LLC
Wholly owned subsidiary of **Pacific Advanced Technology**

June 17, 2015

U.S. Department of State
Directorate of Defense Trade Controls
Compliance & Registration Division
2401 E Street NW, SA-1, Room H1200
Washington, DC 20522-0112

To Whom It May Concern
This letter is in response to the request for public comments to the modifications to Category XII as directed by Executive Order 13563.

Background

Pacific Advanced Technology is a small business, women owned, located in the county of Santa Barbara in the state of California. We develop, manufacture and sell worldwide infrared cameras for specialty application that services the oil, gas, petrochemical, chemical, manufacturing and power industries.

Reading the intent of Executive Order 13563 which was to emphasize the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility we feel that there are some serious issues that need to be addressed that do not accomplish this.

Executive Order 13563 as we understand it had an objective to move some items that the President has determined no longer merit control under the ITAR to control under the CCL. We believe that the language as written to revised category XII will in many cases control technology that doesn't have specific military or intelligence applications or in some cases is definitely covered by the Wassenaar Arrangement on Export Control for Dual-Use Goods and Technologies or is currently covered by the CCL and move it to ITAR. It has increased complexity, caused redundancy in the ITAR and CCL, and has increased confusion with broad and sweeping regulation without definition and specificity. It catches many commercial technologies and foreign availability into ITAR control which severely reduces the ability of American companies to compete in the worldwide market.

Specific examples of our concerns and where category XII as written will severely affect our business are given below. Because of this we believe that category XII as written should not and cannot be let to stand and needs significant rewriting.

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Specific Areas of Concern

Photon Detectors (not encapsulated)

*c) (2). Photon detector, microbolometer detector, or **multispectral detector** infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements*

Our Concern - What is the definition of multispectral detector infrared focal plane arrays. *(Multispectral refers to producing discrete outputs associated with more than one spectral band of response.)*

This is too broad and should be defined to avoid confusion. Example, in the open literature multispectral sometimes refers to detection in different spectral regions such as mid-wave infrared between 3 to 5 microns and longwave infrared between 8 to 12 microns. In other open literature multispectral refers to the detection of sub spectral regions with in the broad mid-wave or long wave region. Example multispectral are bands that are 0.1 micron wide within the spectral region of 3 to 5 microns.

Also it is not clear what discrete outputs associated with more than one spectral band of response mean? Not clear and can be interpreted in many different ways.

This section needs to be rewritten to more clearly define what multispectral means.

Cooled Encapsulated

(4). Two-dimensional photon detector IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, having greater than 256 detector elements;

Our Concern - This description is unclear and inconsistent. First it states Two-dimensional photon detectors ……… having greater than 256 detector elements. Does this refer to cooled encapsulated IRFPA's that are greater than 32 x 32 pixel arrays? If this is the case this is way too restrictive and capturing IRFPAs in our current cameras that are exported under CCL 6A003 and certainly does not harmonize with the Wassenaar Arrangement as well as foreign availability of cooled encapsulated IRFPA as large as 640 x 512 detector arrays or (327,680 detector elements).

Example of foreign availability:
http://www.xenics.com/en/onca-mwir-insb A Belgium company that has a 640 x 512 (327,680) cooled InSb Photon detector camera that is a commercial product. InSb photon detector have a peak response between 2,500 nm and 5,000 nm.

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http://www.electrophysics.com/DbImages/SofEC-ScorpioMW-v11.pdf A French company that has a 640 x 512 (327,680) cooled Photon Detetor core and cameras that are commercial product using HgCdTe photon detector having a peck response between 2,500 nm and 11,000 nm.

http://johotek01.en.made-in-china.com/product/cbMnfdpVnwRk/China-Long-Range-Surveillance-Mwir-Cooled-Infrared-Thermal-Camera-with-600-137-22mm.html A Chinese company that has cooled HgCdTe photon detector cameras with 320 x 256 and 640 x 512 pixel elements as commercial products.

This section needs to be rewritten to more clearly define detector element size in a two-dimensional IRFPA to be harmonized with the Wassenaar Arrangement Dual-Use List and described in Category 6 of the CCL, and to take into foreign availability when determining the number of detector elements in a two-dimensional IRFPA.

Multispectral

c) (6) Multispectral IRFPAs in a permanent encapsulated sensor assembly, having a peak response in any spectral band within the wavelength range exceeding 1,500 nm but not exceeding 30,000 nm;

Our Concern - Again this has the same concern as addressed above in c) 2 for the same reasons. There needs to be a more detailed definition of multispectral.

This is too broad and should be defined to avoid confusion. Example, in the open literature multispectral sometimes refers to detection in different spectral regions such as mid-wave infrared between 3 to 5 microns and longwave infrared between 8 to 12 microns. In other open literature multispectral refers to the detection of sub spectral regions with in the broad mid-wave or long wave region. Example multispectral are bands that are 0.1 micron wide within the spectral region of 3 to 5 microns.

Also it is not clear what discrete outputs associated with more than one spectral band of response mean? Not clear and can be interpreted in many different ways.

We recommend a rewrite of c) 6 with a better description of what is meant by multispectral.

DDCA's

c) (9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:
Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

Our Concern -This is way too restrictive and puts US manufactures at a competitive disadvantage. There are cryocoolers that are sold on the open market in countries other than the US. It also affects OEM's that need to use Cryocoolers in their commercial products with the added cost and restrictions of the ITAR regulation.

Example of foreign availability can be found at http://www.ricor.com/about-us/directions-page/ Ricor is a company in Israel who makes cryocoolers, of their basic model is the K508 and it cools to 77K with a MTTF of 10,000 hours. This is a commercial product.

This specification on cryocoolers needs to be rewritten with the understanding that commercial products are available in the foreign market with much more capability than Cat XII is try to control.

(i) Active cold fingers;

Our Concern - This is way too broad and needs to be defined as what an active cold finger is. All cold fingers in cryocoolers are active in the sense that they change operation to maintain a temperature in the range needed by whatever they are cooling.

This section needs to be rewritten to more clearly define what an active cold finger is.

(ii) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category;

Our Concern - This is way too broad and should take into account that there are many commercial applications that have Dewars specially designed for articles controlled in paragraph (a), (b), or (c) that currently are controlled with export licenses from the Commerce Department.
This regulation should say "specially designed for Military applications".

The paragraph needs to be rewritten so that it doesn't conflict with articles covered on the CCL.

Camera Cores

c) (12) Infrared imaging camera cores (e.g., modules, engines, kits), and specially designed electronics and optics therefor, having any of the following:

- A two-dimensional photon detector IRFPA described in paragraph (c)(4) having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm;

Our Concern - As stated in comments to section c) (4) this regulation does not take into account the foreign availability of products that meet or exceed these specification. Restricting American manufactures will significantly hinder their ability to compete in the worldwide commercial market for applications using camera cores with this restriction.

It particularly hinders our ability to manufacture gas imaging cameras where a key element is the Camera Core as described in this section. Restrictions like this will force companies like ours to form foreign corporations to manufacture products in order to compete in an ever growing international market.

Example of foreign availability:
http://www.xenics.com/en/onca-mwir-insb A Belgium company that has a 640 x 512 (327,680) cooled InSb Photon detector camera that is a commercial product. InSb photon detector have a peak response between 2,500 nm and 5,000 nm.
http://www.electrophysics.com/DbImages/SofEC-ScorpioMW-v11.pdf A French company that has a 640 x 512 (327,680) cooled Photon Detector core and cameras that are commercial product using HgCdTe photon detector having a peck response between 2,500 nm and 11,000 nm.

http://johotek01.en.made-in-china.com/product/cbMnfdpVnwRk/China-Long-Range-Surveillance-Mwir-Cooled-Infrared-Thermal-Camera-with-600-137-22mm.html A Chinese company that has cooled HgCdTe photon detector cameras with 320 x 256 and 640 x 512 pixel elements as commercial products.

This section needs to be rewritten to more clearly define detector element size in a two-dimensional IRFPA to be harmonized with the Wassenaar Arrangement Dual-Use List and described in Category 6 of the CCL, and to take into foreign availability when determining the number of detector elements in a two-dimensional IRFPA.

- A multispectral infrared focal plane array described in paragraph (c)(2) or (c)(6);

Again the definition of multispectral

Our Concern - Again this has the same concern as addressed above in c) 2 for the same reasons. There needs to be a more detailed definition of multispectral.

This paragraph needs to be rewritten with a more defined definition of multispectral that is strictly needed for defense products and does not try to control those technologies and products that fall under "Dual Use" or are already covered by products currently sold with a commerce jurisdiction and controlled under 6A003.

Note to paragraph (c)(12): The articles controlled by this paragraph have sufficient electronics to enable as a minimum the output of an analog or digital signal once power is applied.

Our Concern - Again this language is controlling items that are on the Wassennar Dual Use list and/or controlled by the CCL. This needs to be rewritten to more clearly define sufficient electronics to enable as a minimum the output of an analog or digital signal once power is applied is way to broad and

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captures many commercial products and applications. It should be written with language that says is specifically design for military applications.

c) (16) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor:
- Having two or more axes of active stabilization and a minimum root-mean-square (RMS) stabilization better (less) than 200 microradians;

Our Concern - The way that this is broadly written will capture our CJ products that are currently being controlled by the CCL 6A003 when they are used with commercial stabilization platforms. We use our product for airborne gas leak imaging when flying pipelines not only in the US but worldwide.

With a specification of 200 microradians stabilization and no mention of how this is necessary for defense applications that need ITAR control when commercial stabilization platforms that can meet this specification are readily available.

This clause needs to be rewritten to add the language “that is specifically designed for military applications”. If this is not done the ITAR control of stabilization image platforms which are currently commercially available will severely limit US companies to compete in the international market and add cost and restriction to the US commercial market.

- Fixed-site reconnaissance, surveillance or perimeter security systems or equipment having greater than 640 detector elements in any dimension;

Our Concern - This language captures systems that are covered under the Wassenare Dual Use and are have foreign availability. We have products that are used for fixed-site surveillance in oil, gas, chemical and manufacturing facilities looking for gas leaks. These cameras were specifically design for commercial applications. In some instances they need to have more than 640 elements in any direction to be able to cover the necessary field of regard that our customers need.

This paragraph needs to be rewritten calling out “design for military applications” to insure that it doesn’t conflict with products that are already in the commercial market.

- Combat vehicle, tactical wheeled vehicle, naval vessel, or aircraft pilotage systems or equipment having a variable field of view or field of regard (e.g., electronic pan or tilt), and either an IRFPA article controlled in this subchapter with greater than 640 detector elements in any dimension.

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Our Concern - As mentioned in the previous paragraph the way this is written is going to capture our commercial products that are flown on airborne platforms to survey and area for gas leaks where buried and above group gas pipes exist worldwide.

This paragraph needs to be rewritten calling out "design for military applications" to insure that it doesn't conflict with products that are already in the commercial market.

- Multispectral imaging systems or equipment that either incorporate a multispectral IRFPA described in paragraph (c)(2) or (c)(6), or classify or identify military or intelligence targets or characteristics;

Our Concern -This should be rewritten change "or" to "and" so that it doesn't capture commercial products like ours that are being used for gas leak imaging. Also a definition of intelligence targets needs to be spelled out so that it doesn't leave room for interpretation.

c) (19) Systems or equipment that project radiometrically calibrated scenes directly into the entrance aperture of an electro-optical or infrared (EO/IR) sensor controlled in this subchapter within either the spectral band exceeding 10 nm but not exceeding 400 nm, or the spectral band exceeding 900 nm but not exceeding 30,000 nm; or

Our Concern - There is no definition of radiometrially calibrated and the way this is written it can capture any number of commercial product that perform thermographic image analysis and display the temperature of the scene in the view finder of the camera. We are particularly concerned because we display information on the concentration and type of gases that are observed leaking in the view finder for strictly commercial applications. These products are currently covered by the CCL 6A003. This language will pull them back to ITAR and make it very difficult to operate our business and compete in the worldwide market.

This paragraph needs to be rewritten calling out what is meant by "*radiometrically calibrated*" taking into account what makes it designed for defense applications and not commercial applications.

c) (20) Developmental imaging systems or equipment funded by the Department of Defense.
Note 1 to paragraph (c)(20): This paragraph does not control imaging systems or equipment (a) in production; (b) determined to be subject to the EAR via a commodity jurisdiction determination (see §120.4 of this subchapter), or (c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications.

Our Concern - This note helps mitigate some of our concerns, however as we perform product improvement for our commercial items and we need to have a review to determine that our improvement are subject to the EAR via commodity jurisdiction we are seriously concerned that the language in the modification to Category XII in many of the paragraphs in c) (4) through c) (19) will not allow for a commodity jurisdiction. It is important that we have forward thinkers writing these rules and regulations that understand the technology and products that need to compete in the international market must not be hampered by antiquated, poorly written, and too restrictive language as is the case for so much of section c)

Our recommendation is that section c) needs a serious rewrite as stated above.

(e)(10) is added for specially designed drive, control, signal or image processing electronics.

Our Concern – this is unclear and overly broad. Virtually any IR camera that uses an IRFPA will have some portion of its electronics that "drive," "control" and/or "image process" data from the IRFPA. At least some portion of the IR camera electronics is always unique (specially designed?) for interfacing to a particular IRFPA. Thus, as written this will control at least some portion of the electronics of any IR camera that uses an IRFPA controlled in this category.

To achieve EAR control of a civil/commercial IR camera, a manufacturer would need to identify exactly which portion of the camera electronics is specially designed for the IRFPA (which is not at all clear), and then make that portion tamper proof according to the Note to paragraph (e), how to make something *sufficiently tamper proof* is not at all clear either.

Worse still we would also need to determine whether the electronics that "drive," "control" and/or "image process" data from the IRFPA is specially designed for the IRFPA die controlled in (c)(2) or the packaged/encapsulated IRFPA controlled elsewhere in (c); e.g., in (c)(5).

If anything, the electronics really has little to do with the packaging and is more logically associated with the IRFPA die controlled in (c)(2). Since (c)(2) controls practically every IRFPA the end result of the way this paragraph is written would put all our commercial products as ITAR controlled item.

Our recommendation is that (e) 10 is rewritten to say "specially designed for military applications".

Best Regards,

____

Michele Hinnrichs
Chief Executive Officer

Georgia Tech Research Corporation   Georgia Tech Applied Research Corporation

July 6, 2015

Office of Defense Trade Controls Policy
Department of State
Washington, DC
By email to DDTCPublicComments@state.gov

RE: ITAR Amendment—Category XII (RIN 1400-AD32)

Dear Madam/Sir,

I am writing on behalf of the Georgia Tech Research Corporation and the Georgia Tech Applied Research Corporation (collectively Georgia Tech), non-profit supporting organizations of Georgia Institute of Technology, to provide the following comments in response to the Department of State's Proposed Rule for *Amendment to the International Traffic in Arms Regulations: Revision to U.S. Munitions List Category XII - RIN 1400-AD32*. The Georgia Tech Research Corporation and Georgia Tech Applied Research Corporation serve as the contracting entities for Georgia Institute of Technology, one of the teaching and research institutions operated and managed by the Georgia Board of Regents of the University System of Georgia. The Institute is organized in six academic colleges plus the Georgia Tech Research Institute which was established by the Georgia General Assembly as a department within the Institute. With research expenditures totaling over $730 million, about 40% of Georgia Tech's funding for externally sponsored research is awarded by agencies of the United States Department of Defense (DOD), about 14% is funded by the National Science Foundation, and 14% by private industry while the balance comes from a number of federal and non-federal sponsors and private foundations.

With a significant DOD research portfolio at Georgia Tech is sensitive to the economic and technological value of some of the technologies described within the proposed Category XII. Our research portfolio includes many dual-use technologies within proposed Category XII including astronomy and space science, environmental, meteorological and oceanographic monitoring, telecommunication, photonics, computer processor-memory interconnects, materials engineering, thermal management, energy storage, energy conversion, photovoltaic devices, groundwater management, computational sciences, imaging and molecular medical diagnostic tools. Given their diverse technical specifications, variety of sponsor requirements, and the federal laws that apply, it is important that technologies subject to ITAR be specifically described with clear delineations between items that have military uses and those that have non-military commercial end uses.

We recommend that the Department of State consider adding a clarification to Category XII such as:

> *Category XII does not apply to items that are specifically made for non-military end uses, such as environmental/meteorological monitoring, including stationary ground-based systems and telescope instruments used in research or developed for commercial end use.*

In addition, we believe it is important to address several individual sections within the proposed regulation to add clarifications and additional definitions.

ITAR XII (b)(2)
There are commercial products (e.g., laser trackers) which meet this definition that cannot readily be converted to defense use. We recommend that the technical parameters be changed to exclude items already commercially available.

ITAR XII (b)(3)(i)(ii)
Commercially available thermal imaging infrared camera products would be ITAR-controlled under the proposed definition. We encourage DOS to reconsider the proposed technical parameters.

ITAR XII (b)(6)-(8)
Georgia Tech uses and develops LiDAR systems for a variety of research purposes ranging from environmental/meteorological projects to military applications. While the latter warrant control, under the proposed rule, some of our environmental/meteorological systems in development (and others that are commercially available) have specifications described in paragraphs (7)-(8).

Therefore, we request the Department of State consider adding a clarification to Category XII (b) (6)-(8) such as:

> *Category XII (b) (6)-(8) does not apply to LiDARs or other laser range-gated systems or equipment built for environmental, meteorological or other non-military research purposes or LiDARs or other laser range-gated systems or equipment already commercially available.*

ITAR (b)(11) - (13)
We would like to applaud the Department of State for increasing the level of power triggering control from 1W to 2W under (b)(11) and (b)(12). However, in (b)(13) the "power density of xxW/cm2" is used as a measure. The power density depends on how the laser is focused using lenses external to the laser itself. As written, this will allow for varying interpretation and confusion as the issue is primarily dependent on how the laser is focused and used. To prevent confusion and varying interpretations, we recommend that Department of State to consider clarifying Category XII (b)(13) as follows:

> *Clarify the power density in terms of Watts and focusability of the laser.*
> *Review the requirements to exclude lasers that are already commercially available.*

ITAR XII (b)(14)
As written, Category XII (b)(14) implies that the funding source (such as DOD) for research involving lasers or laser systems will dictate whether or not the systems should be controlled as a munition. Per Note 1 to paragraph (b)(14), if a contract fails to include language that the system or equipment being developed is for both civil and military applications, then the system or equipment would therefore be ITAR-controlled. It should be noted that much initial work on lasers and laser systems is internally funded research or under DOD "6.1" basic research funding, based on public domain information, or conducted by universities as fundamental research in accordance with National Security Decision Directive 189 (NSDD-189). Thus, the proposed rule differs from the current policy whereby research supported by the DOD, without access or dissemination controls, is considered fundamental research under the ITAR.

We request the Department of State to consider adding a clarification to Category XII (b)(14) such as:

> *Category XII (b)(14) excludes lasers not meeting the requirements for a military end use, even if developed or funded by the Department of Defense. Furthermore, development does not include research that meets the requirements of fundamental research.*

ITAR XII Note 2 to paragraph (c)(2): 12 (iii)
Requirements in this section may have a scientific impact in the US and may provide a competitive advantage to foreign companies that are not similarly constrained. For example, the bolometers, invented in 1878 by Samuel

Pierpont Langley, led to significant advances in research. Bolometers vary in size and technical specifications and can be purchased from a number of US Suppliers which, arguably, will have limitations and thus an economic disadvantage to non-US suppliers under the proposed requirements. Restrictions in the use of these instruments may have an impact in academic research settings if access must be controlled.

Undefined Terms ITAR XII(c)(2), (c)(4) and (c)(12)

We request the Department of State consider defining the following terms:

- *XII(c)(2) – "Integrated"*
- *XII(c)(4) – "Permanent encapsulated sensor assembly"*
- *XII(c)(12) – "Infrared imaging camera core"*

ITAR XII(c)(9)

Historically, infrared focal plane arrays (IRFPA) used in land-based telescope were developed for spaceflight or military use. However, such systems are now commonly used for many commercial applications. As written, ITAR XII(c)(9) would apply to commercially available Dewar's, cooling systems and electronics that were not specifically designed to be used with controlled IRFPAs simply because of their use with a controlled IRFPA. These commercially available devices could be purchased and used for other purposes without being subject to the ITAR, but once the products are associated with a controlled IRFPA, the devices would need to be controlled. Because these components would be subject to ITAR restrictions, details of their design or integration into the IRFPA system could not be discussed in scientific publications. However, because these are commercial products, it is very possible that details of their design and use are already in the public domain.

We request the Department of State to consider adding clarification to Category XII (c)(9) such as:

> *Category XII (c)(9) excludes IRFPA Dewar cooler assemblies and cooling systems that are commercially available or custom components made for non-military, scientific purposes including research that meets the requirements of fundamental research.*

ITAR XII(e)(7)(i)

Originally developed to compete with steam engines, Stirling cryocoolers are based upon technology that was developed in the 1800s. This technology and knowhow has been well described in the public domain and no longer warrants this level of control.

We suggest the Department of State add a clarification to Category XII (e)(7)(i) such as:

> *Category XII (c)(9) excludes Stirling cryocoolers that are commercially available or custom components made for non-military, scientific purposes including research that meets the requirements of fundamental research.*

ITAR XII(e)(9)

Is overly broad in that it can include optical elements that are not enclosed or attached to the IRFPA Dewar cooler assembly. As written, this could be read to include all optical elements within the beam path of a scientific instrument which would have unintended consequences for foreign graduate students developing custom optical elements as part of their studies.

We recommend that the Department of State reconsider Category XII (e)(9) to be more specific in its application.

ITAR XII (c), (e) and (f)

We request the Department of State to consider defining the following terms:

Resonator (it is unclear if this is for a resonator for gain).

We request the Department of State to consider adding clarification to Category XII (c) and (e) such as:

ITAR Category XII XII(c) and XII(e) excludes assemblies, parts and components that are used in conjunction with an IRFPA not meeting the requirements for a military end use.

Georgia Tech commends the Department of State on the provisions of the proposed rule and recognizes the importance of safeguarding technologies and items under ITAR XII. We appreciate the opportunity to provide the comments on the ITAR Amendment—Category XII. We hope that these comments will facilitate an understanding of how the technologies are developed and used at institutions of higher education such as Georgia Institute of Technology. The research enterprise in the United States is critical to the economic advancement of our country and having clear and concise export regulations helps ensure that innovation is not stifled in performing fundamental research.

Sincerely,

Jilda D Garton
Vice President for Research and General Manager
Georgia Tech Research Corporation
Georgia Tech Applied Research Corporation

July 6, 2015

Regulatory Policy Division
Bureau of Industry and Security
US Department of Commerce
Room 2099B
14th Street and Pennsylvania Avenue NW
Washington, DC 20230

And

Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
Bureau of Political Military Affairs
Department of State
Washington, DC 20522

Sent via email to: publiccomments@bis.doc.gov and DDTCPublicComments@state.gov

Re: RIN 0694-AF75 - Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the United States Munitions List (USML) and RIN 1400-AD32 Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

Dear Sir/Madam:

Google is pleased for the opportunity to provide comments to the US Department of Commerce and the Department of State on the Export Administration Regulations (EAR) proposed rule (Department of Commerce Bureau of Industry and Security, 80 Fed. Reg. 25798 (proposed, May 5, 2015), hereinafter "Commerce Rule") and the Department of State rule (Department of State, 80 Fed. Reg. 25821 (proposed, May 5, 2015), hereinafter "State Rule"). We understand that the proposed rules in question are in furtherance of the agencies' ongoing export control reform objectives. While we appreciate the difficult undertaking that accompanies this effort, we believe the proposed rules add to the existing regulatory complexity, both from a logistical and technical perspective, rather than reduce it. As demonstrated below in our specific comments, the several proposed additions to Category XII of the United States Munitions List (22 C.F.R. Part 121, "USML") are unnecessarily overbroad and render the line between State and Commerce jurisdiction much less bright than what is accomplished under the current regulations. Furthermore, the proposed changes introduce concepts that are confusing from a technical standpoint, making the rules hard to apply in practice. Finally, under these proposed changes, a large number of commercially globally available items controlled under the EAR (15 C.F.R. Part 730 *et. seq.*) will either fall under State jurisdiction or will be subject to the same International Traffic in Arms (22 C.F.R. Part 120 *et. seq.*, "ITAR") licensing policy (i.e., a license will be required for exports and deemed exports worldwide) despite remaining under EAR control. This will serve to hurt US industry while benefiting non-US competitors. Given the current technology landscape in the affected sectors, imposing a wall around this technology will give the false illusion of protecting it, when, in reality, this technology is already available and being developed outside the US. Sealing it off in the US will force non-US companies to design out/around US components, thereby harming business for US companies in areas where the technology is already readily available from non-US suppliers. It will also likely discourage US companies from developing technology in the United States. We have provided several recommendations below in an attempt to address these issues, but ultimately, our underlying recommendation would be to re-draft the rules from scratch; tweaking them to address the problematic aspects may actually further complicate the rules and will continue the confusing layers of cross-referencing and wording inter-dependency that characterizes the proposed rules, as currently worded.

Comments to State Rule

Provision: Cat. XII(b)(6): Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);

Note to paragraph (b)(6): This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less.

- **Comment**: This proposed provision would capture LIDAR systems used in self-driving car applications even if the system is solely designed for civil automotive applications. This is because it would not qualify for the "Note to paragraph (b)(6)" (hereinafter, referred to as "Civil Automotive Exception"). Specifically, the system would not meet the criteria of the Civil Automotive Exception if the range of the LIDAR system exceeds the range of 200m. It is our belief that many commercial companies are developing self-driving car LIDAR technology that would exceed 200m. In particular, we believe that the range must exceed 200m for safety reasons. For example, the system's range needs to be greater than 200m when the vehicle is making unprotected left turns in the presence of cars that are driving at higher speeds regardless of whether they decelerate or not. A greater than 200m range is also necessary for spotting oncoming emergency vehicles so that the self-driving car can safely pull over and move out of the path of such vehicles. Furthermore, in rural areas where speed limits tend to be higher, being able to detect oncoming traffic at a greater range than 200m is again important from a safety perspective.

- **Recommendation**: We request that the range in the Civil Automotive Exception be increased to 400m to account for current technology developments as well as future innovation in this space, both of which will serve to increase overall self-driving car safety.

Provision: Cat. XII(b)(8): LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned

aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):

(iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geigermode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements.

- **Comment**: This proposed provision potentially captures LIDAR systems used in civil automotive applications. Specifically, "incoming" bandwidth refers to detector bandwidth and determines minimum resolvable pulse length, which, in turn, drives minimum detectable feature separation. For a self-driving car, a sufficiently short light pulse and the ability to resolve this pulse allows the car to effectively distinguish between objects that are positioned on the same vector with respect to the car, and that are spatially close, such as a pedestrian standing near a car. Detector bandwidth determines the minimum width (in the time domain) of a resolvable pulse, which corresponds to the physical length of a collection of photons in the spatial domain. A long light pulse of 10ns (which would equate to 100MHz) is 3m long and could reflect off a pedestrian and also a vehicle 1m away from the pedestrian; a light pulse of 1ns (which would equate to 1000MHz) is 30cm long and would have separate reflections off the pedestrian and vehicle generating much more of an accurate read-out of obstacles in the vicinity. In short, having a bandwidth of 1000MHz allows the system to distinguish between objects/people that are spatially close and on the same vector and to react accordingly to achieve road safety goals. A clock bandwidth of 100 MHz is lower than many common operating bandwidths; the clock in a processor that would control even a trivial LIDAR system could be expected to run faster than 100 MHz. Furthermore, a detector bandwidth of 100 MHz is lower than a common detector and amplifier could be expected to have (and much slower than many currently available components). If the proposed control is intended to address "incoming" or detector bandwidth, it would likely capture many standard commercially available LIDAR systems that are intended and designed for civil automotive self-driving car applications.

  In addition to the bandwidth considerations noted above, we also put forth that the trigger point of 128 elements is too restrictive from a safety perspective for civilian self-driving car applications. Specifically, such cars need a LIDAR system to detect with accuracy foreign objects and debris ("FOD") on the road. The typical range of angle of slope on a road is +/-8 deg. The car needs to be a certain distance away from the FOD in order to react to it safely (150m), and a typical dangerous FOD is 15cm tall. This means that the sensor requires on the order of 250 detectors to cover the complete field of view with enough resolution to maintain safety. It should be noted that collision avoidance technology, including LIDAR systems, have been recognized as playing a key role in preventing rear-end crashes[1].

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[1] *See* http://www.ntsb.gov/safety/safety-studies/Documents/SIR1501.pdf, and http://c.ymcdn.com/sites/www.mapps.org/resource/resmgr/Federal_Issues_LIDAR/LIDAR_Systems_and_Safety_for.pdf

Driver-assistance cars do not need this same level of FOD detection mainly because a driver would be able to step in and react whereas in a self-driving car, the system itself needs to react. As such, this parameter, as currently worded, would actually discourage safety for civilian self-driving cars.

Foreign availability: we note that many foreign manufacturers have developed technology in this space. Specifically, Reigl, an Austrian company, Sick AG, a German company and Hokuyo LTD, a Japanese company have all developed LIDAR systems that operate at over 100MHz.

- **Recommendation**: We request that the same Civil Automotive Exception (with the amendment of extending the range to 400m) that appears in the Note to paragraph (b)(6) be included in (b)(8) to avoid capturing commercial LIDAR systems that are designed and intended for use in civil automotive applications.

  If the intention is to capture "incoming" or detector bandwidth, we recommend that the limit be increased to 1000MHz which would cover a standard LIDAR system designed for civil automotive applications. We also recommend that the element trigger be "greater than 256 elements." Both of these changes would serve to encourage companies working in this space to continue to work on critical safety features.

Provision: Cat. XII(c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;

- **Comment**: Due to the extremely wide range of wavelength parameter, this sweeping control would potentially capture IRFPAs that are intended by design and function for use in commercial LIDAR systems used in self-driving cars. Such IRFPAs, including highly sophisticated arrays, are currently under the jurisdiction of the Commerce Department so this proposed control would have the effect of placing commercially world-wide available EAR-controlled IRFPAs under ITAR jurisdiction. This would not only have devastating effects on US businesses, but it will also serve to bolster foreign competitors' efforts in this space. Indeed, many companies may elect to move operations abroad and source commercially available non-US components to avoid the hugely negative impact of these controls.

  With respect to the term "focal plane array" itself, it is unclear whether detector elements that are purchased separately on multiple chips but are ultimately put together on a plane would actually qualify as a "focal plane array."

  Additionally, linear arrays (single line of detectors) can only form images when coupled to a scanning system, which makes them very inefficient as night vision applications, but are necessary to form the 360 degrees field of view that self-driving vehicles require.

Foreign availability: Many non-US companies have IRFPAs that would be caught by this control. For example, Hamamatsu, a Japanese company, has an array in the range of 900-1600nm that would be caught under the proposed control.

- **Recommendation:** Include an exception/carve out for IRFPAs that are specially designed and intended for use in LIDAR systems used in civil automotive applications and having a peak response within the wavelength range not exceeding 1800 nm. Also, we recommend amending the definition of an IRFPA to include the monolithic nature of it (and exclude arrays formed of multiple dies assembled together in a system) as well as exclude linear arrays.

Provision: Note 1 to paragraph (c): A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

- **Comment:** To our knowledge, the term "permanent encapsulated sensor assembly" is not an industry-wide used term. As such, this will inevitably lead to confusion as well as inconsistency in how it is applied when interpreting the related controls. Even with the definition provided in Note 1 to paragraph(c) as well as in sec. 772.1 of the EAR (commented on below), it is hard to apply since the requirements of the definition in their strictest sense cannot be met. Specifically, as far as we are aware, many focal plane arrays that are in some sort of encapsulation can still be disassembled without damaging or destroying the IRFPA. However, this can generally only be done by specialized tools by someone who has detailed awareness of the design of the IRFPA. Is the term "permanent encapsulated sensor assembly" intended to capture closed and non-serviceable encapsulated systems that could be disassembled by a specialized technician using specialized tools without damaging or destroying the IRFPA **or** is it only intended to capture closed and non-serviceable encapsulated systems that cannot be disassembled without damaging or destroying the IRFPA? If the latter, it is unclear to us whether any assembly would actually meet that criteria.

- **Recommendation**: If the technical data is already controlled and one would need the design technology in order to be able to disassemble the assembly without damaging or destroying the IRFPA, it makes sense to modify this note as well as the definition set forth in sec. 772.1 of the EAR to read as follows: "*A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) is designed as a closed and non-serviceable system intended to prevent direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA.*"

Provision: Note 1 to paragraph (f): Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this

category, remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.

- **Comment**: Note 1 to paragraph (f) has the potential to yield unreasonable consequences. For example, if Manufacturer A is designing a focal plane array controlled under the EAR, the related design technology would be controlled under the EAR. If Manufacturer B takes that same technology though and designs an ITAR-controlled focal plane array, that design technology that was controlled under the EAR would now become controlled under the ITAR even though it may have nothing to do with the parameters triggering control of the focal plane array under the ITAR.

- **Recommendation**: This Note should be revised to make clear that technical data that is "directly related" to an ITAR-controlled item (covered by the mentioned controls in the Note) is limited to technology that is specific to the parameters that render the device controlled under the ITAR and would not include generic design technology for focal plane arrays that would be covered under the EAR.

<u>Comments to Commerce Rule</u>

Provision*: *§ 772.1 Definitions of terms as used in the Export Administration Regulations (EAR). Permanent encapsulated sensor assembly. (Cat 6) A permanent encapsulated sensor assembly (e.g. sealed enclosure, vacuum package) containing an infra-red focal plane array (IRFPA) that prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

- **Comment**: To our knowledge, the term "permanent encapsulated sensor assembly" is not an industry-wide used term. As such, this will inevitably lead to confusion as well as inconsistency in how it is applied when interpreting the related controls. Even with the definition provided in Note 1 to paragraph(c) as well as in sec. 772.1 of the EAR (commented on below), it is hard to apply since the requirements of the definition in their strictest sense cannot be met. Specifically, as far as we are aware, many focal plane arrays that are in some sort of encapsulation can still be disassembled without damaging or destroying the IRFPA. However, this can generally only be done by specialized tools by someone who has detailed awareness of the design of the IRFPA. Is the term "permanent encapsulated sensor assembly" intended to capture closed and non-serviceable encapsulated systems that could be disassembled by a specialized technician using specialized tools without damaging or destroying the IRFPA **or** is it only intended to capture closed and non-serviceable encapsulated systems that cannot be disassembled without damaging or destroying the IRFPA? If the latter, it is unclear to us whether any assembly would actually meet that criteria.

- **Recommendation**: If the technical data is already controlled and one would need the design technology in order to be able to disassemble the assembly without damaging or destroying the IRFPA, it makes sense to modify this note as well as the definition set forth in sec. 772.1 of the EAR to read as follows: "*A permanent encapsulated sensor* *assembly (e.g., sealed enclosure, vacuum package) is designed as a closed and non-serviceable system intended to prevent direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA."*

Provision: § 742.6 Regional stability. (a) * * * (8) Special worldwide RS license requirement for specified items controlled in Category 0 or 6. A license is required to export or reexport the following items to all destinations, including Canada: (i) ''Technology'' controlled under ECCN 0E987; (ii) All commodities controlled under ECCNs 6A002; (iii) All commodities controlled under ECCN 6A990; (iv) ''Software'' controlled under ECCN 6D002 for the ''use'' of commodities controlled under 6A002.b; (v) ''Software'' controlled under ECCN 6D003.c; (vi) ''Software'' controlled under ECCN 6D991 for the ''development,'' ''production,'' or ''use'' of commodities controlled under ECCNs 6A002, 6A003, or 6A990; (vii) ''Software'' controlled under ECCN 6D994; (viii) ''Technology'' controlled under ECCN 6E001 for the ''development'' of commodities controlled under 6A002 or 6A003; (ix) ''Technology'' controlled under ECCN 6E002 for the ''production'' of commodities controlled under 6A002 or 6A003; (x) ''Technology'' controlled under 6E990; and (xi) ''Technology'' controlled under ECCN 6E994.

- **Comment**: This proposed regional stability reason for control imposes a worldwide licensing requirement for items classified under several ECCNs. Not only is this type of global control unprecedented under the EAR, but, in addition, it is being imposed on several items that were previously classified as EAR99 (e.g., those items covered under newly created ECCNs 6D994 and 6E994 as well as the additional items that will now be caught under the proposed re-wording of ECCN 6A990 which would expand its scope to include ROICs for *all focal plane arrays* controlled under 6A002a.3). In short, this means that items that previously required no license at all (except for export to the embargoed countries) will now require an export license to be shipped everywhere including Canada. Needless to say, this will result in a huge burden on industry as well as the Commerce Department, which will have to process both additional export/reexport and deemed export/deemed reexport license applications for the covered items. Since projects involving this type of technology and source code have not been thus far subject to restrictive export controls, it is highly likely that non-US nationals have already been working on them and continue to work on them today. It is also fairly common for collaboration on projects to occur across offices and across countries. The proposed control would require limiting cross-country collaboration, restricting those who can work on the projects to US nationals and/or obtaining licenses for all non-US nationals working on the project. Applying for export and deemed export licenses would impose a large burden on both the Commerce Department and industry, as described earlier, and raises other issues caused by a shift in licensing policy, described further below. It will also inevitably affect the marketability of US parts and components as well as software and technology.

Provision: (b) Licensing policy.—(1) Licensing policy for RS Column 1 items or items subject to worldwide RS control…(iv) Applications for exports or reexports of software or technology described in paragraphs (a)(8)(i), (a)(8)(iv), (a)(8)(v), (a)(8)(vi), (a)(8)(viii), and (a)(8)(x) will be reviewed with a presumption of denial. There is also a presumption of denial for technology described in paragraph (a)(8)(ix), unless it is ''build-to-print technology'' that is required for integration, mounting, inspection, testing, or quality assurance (e.g., necessary to meet International Standards Organization (ISO) certification), which will be reviewed on a case-by-case basis.

- **Comment**: Under the proposed licensing policy for items subject to the RS worldwide control, many items that are currently EAR99 (items controlled under the proposed rewording of 6A990) in addition to numerous other items controlled under 6A002, 6D003.c, and 6E001 that were eligible for various license exceptions would now be subject to a licensing policy of denial. This shift in licensing policy, creation of a worldwide licensing requirement, and removal of eligibility of certain license exceptions serve to pseudo-treat these items as ITAR-controlled even though these items are actually currently controlled under the EAR. This would serve to potentially severely impact US industry as companies seek alternative options that would not be tainted by US export licensing policies in this space. Similar long-lasting repercussions were seen in the space and satellite industry when those areas were subjected to ITAR controls and foreign companies then looked to suppliers outside the US (with some foreign companies specifically desiring to go "ITAR free") to avoid subjecting their products and technologies to control under the ITAR. In our view, this would not fall within the spirit of export control reform.

Provision: 6D991 ''Software,'' n.e.s., ''specially designed'' for the ''development'', ''production'', or ''use'' of commodities controlled by 6A002, 6A003, 6A990, 6A991, 6A996, 6A997, or 6A998.

- **Comment**: The proposed revision to 6D991 results in controlling software that is currently controlled as EAR99 (e.g., software "specially designed" for the "development," "production," or "use" of all 6A002 and 6A003 items). Furthermore, the reason for control of RS would result in a license being required for all covered software to all countries and non-US nationalities in the case of deemed exports. Again, controlling this type of software would be disruptive to industry since much of this software is currently non-controlled. Moving from a state of non-control to a state of highly-controlled will inevitably result in large impact from a licensing perspective as well as from a cross-nationality and cross-country collaboration perspective. Finally, such a control will help further non-US business interests working in this space whose software and technology are not subject to unilateral US export controls.

Provision: 6D994 ''Software'', n.e.s., ''specially designed'' for the maintenance, repair, or overhaul of commodities controlled by 6A002, 6A003, or 6A990.

Provision: 6E994 ''Technology'' ''required'' for the maintenance, repair, or overhaul of commodities controlled under 6A002, 6A003, or 6A990.

- **Comment**: The proposed creation of ECCNs 6D994 and 6E994 would result in controlling low-level software and technology that is currently non-controlled (i.e., EAR99) and already developed abroad by various non-US focal plane array manufacturers. Furthermore, the reason for control of RS would result in a license being required for all covered software and technology to all countries and non-US nationalities (in the case of deemed exports). Thus, we would move from a regulatory environment of not requiring any export or deemed export licenses (except for the embargoed countries) to one where licenses would be required for all covered items regardless of destination or nationality. Again, we believe this would create a significant burden on both US companies and BIS. Further, it would serve to ultimately hurt US businesses by having the secondary effect of encouraging the use of non-US manufacturers and developers so as to avoid the draconian implications that would result from using items that are subject to ITAR-like licensing requirements and policies.

Please do not hesitate to contact us via email (lianasebastian@google.com) or phone (650-214-3036) with any questions or comments regarding this submission.

Sincerely,

Liana Sebastian
Export Compliance Counsel, Google Inc.

Government of Canada Gouvernement du Canada
Embassy of Canada Ambassade du Canada

July 6, 2015

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Comments on "Amendments to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII"

Comments on "Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control under the United States Munitions List (USML)"

Please find attached the Government of Canada's comments on the subject proposed rules.

Canada supports the U.S. Administration's overall goal of strengthening national security by undertaking reforms that will significantly reduce the regulatory burden and costs associated with no- to low-risk transactions of controlled goods. However, Canada is concerned that the proposed imposition of a new licencing requirement would not achieve this objective by causing unnecessary complications to the highly integrated defence industrial base we share. Accordingly, Canada respectfully requests that the proposed rules be revised to ensure that under their final form, no item will require an export licence to Canada where none is presently required.

During the regulatory review process, Canadian and U.S. officials have maintained a much- appreciated dialogue regarding the proposed changes. We remain available for further cooperation to find mutually beneficial solutions.

Sincerely,

Gilles Gauthier
Minister (Economic)

Canada

July 6, 2015

Comments on Amendments to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

Comments on Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control under the United States Munitions List (USML)

The Government of Canada welcomes the opportunity to provide comments on the proposed changes to the *International Traffic in Arms Regulations: U.S. Munitions List Category XII - Fire Control, Range Finder, Optical, and Guidance and Control Equipment;* and the *Revisions to the Export Administration Regulations (EAR) Commerce Control List Category 6 – Sensors and Lasers.*

Canada and the U.S. share the responsibility of continental defence and we both benefit from an integrated industrial base. As such, Canada is encouraged by President Obama's comprehensive inter-agency review of the U.S. export control system, also known as Export Control Reform (ECR). However, Canada wishes to express its concern that, under the proposed regulatory changes, a significant number of products currently listed under the *U.S. Department of Commerce's Commerce Control List Category 6* (Sensors and Lasers) may require an export licence to Canada, where none is currently required.

For example, under the proposed rule, commercial items related to infrared detection, and their associated software and technology, which currently may be exported to Canada without an individual license, would be subject to new license requirements. These items include optical detectors, image intensifier tubes, focal plane arrays and read-out integrated circuits that are used in cameras and other equipment. These items have extensive and growing uses in commercial applications, such as industrial process control, gas detection, mapping, home inspection, spectroscopy, semiconductor, search and rescue, maritime, security surveillance, firefighting, medical imaging, laboratory, astronomy and automotive applications.

As such, Canada respectfully requests that in further reviewing the proposed changes, due consideration be given to the following factors: the existing cooperation between our countries on issues relating to exports controls at multilateral, regional and bilateral levels; the longstanding Canada-U.S. defence relationship; the highly integrated Canada-U.S. defence industrial base and trade relationship; the reciprocity of favourable export regulations between trusted partners; and the goals of the Export Control Reform to strengthen national security by undertaking reforms that will significantly reduce the regulatory burden and costs associated with no- to low-risk transactions of controlled goods.

1. The proposed regulatory changes should take into account the longstanding Canada-U.S. defence relationship

Canada and the United States are each other's most important security and defence partners. Defence relations between our two countries are longstanding, well entrenched and highly successful. Since World War II, the two countries have successfully shared defence resources to secure supply and defend North America. There are more than 600 Memoranda of Understanding (MOUs) and agreements between the two nations supporting joint cooperation mechanisms, development of defence technology and the interoperability of our fighting forces.

Our militaries need to continue to work together to meet our respective defence and security needs and that of our allies and foreign partners. As such, requiring a new export licence for certain products to Canada challenges existing policies in defence cooperation.

Canada respectfully requests that proposed regulatory changes reflect the historical and political relationship between Canada and the U.S. in the exchange of defence goods.

2. The proposed regulatory changes should not negatively impact the highly integrated Canada-U.S industrial base

Over the past four years, the United States exported over USD $1.1 billion in military equipment, binoculars, and laser equipment to Canada which includes products under *USML Category XII* classification of *Fire Control, Range Finder, Optical, and Guidance and Control Equipment* defence products.

Our longstanding defence relationship has helped develop and sustain a deeply integrated defence industrial base that is celebrated on both sides of the border. Just recently, the House Armed Services Committee highlighted the importance of the North American Defence Industrial Base in its report accompanying the *National Defence Authorization Act*, noting that:

> The committee acknowledges the vital role played by the defense industrial base in supporting the Armed Forces of the United States, noting that a cost-effective, healthy base that is responsive to U.S. military requirements is essential to achieving U.S. national security objectives. The committee further notes that in light of robust trade relations, a shared interest in the defense of North America, and responsibilities as the only North American allies within the North Atlantic Treaty Organization, both the United States and Canada benefit from the North American Defense Industrial Base relationship. Therefore, the committee is supportive of the strong, integrated, and widely dispersed industrial base in North America reflecting the economical use of research, development, and production resources, as laid out in the Department of Defense Instruction 2035.01 dated February 27, 2006.

The Canadian defence and security industrial base consists of over 2,000 firms, many of which have parent companies or subsidiaries in the United States. Every day, U.S. and Canadian firms work in collaboration to service defence contracts in both countries and abroad. In fact, every year, the Canadian Commercial Corporation manages, on average, $1 billion in contracts for goods and services delivered by Canadian companies to the DOC and NASA. Companies on both sides of the border established product lines, marketing plans, distribution networks, and supply chains based on the current regulatory environment. A tightening of controls, as proposed in the revised rules, would disrupt these trade flows.

Canada respectfully requests that proposed regulatory changes consider the economic impact upon our integrated defence industry.

3. The proposed regulatory changes should maintain reciprocity regarding export control regulations between trusted partners

The unilateral imposition of an export licence would increase unnecessary administrative costs in the exchange of defence and security products. Since the Second World War, Canada and the U.S. have not required export permits on many military and strategic goods and technology traded between them under the ITAR, EAR and Canada's Export Control List, an arrangement which Canada believes continues to serve our mutual interests.

From Canada's perspective, the goods and technology that will be affected by this proposed regulatory change do not represent a strategic risk to regional defence and security for export to the United States. However, under the proposed regulatory changes, the same items exported to the U.S. without a Canadian permit would require a U.S. licence to be re-exported back to Canada. This policy change would result in undue administrative burden unbecoming of our historical reciprocity.

Canada respectfully requests that the proposed regulatory changes consider existing policies that promote the reciprocity of trade of controlled goods and technology.

4. The regulatory changes should reflect ongoing Canadian and U.S. cooperation on export control issues at the multilateral, regional and bilateral levels

Canada and the U.S. have a long history of cooperation on export control issues at the multilateral, regional and bilateral levels. Both countries, as members of all the multilateral export controls regimes, have worked together to address issues of mutual concern relating to the control of strategic and military goods and technology around the world. The same can be said for the export control-related cooperation of both countries at the Organization of American States.

The establishment of Canada's *Controlled Goods Program,* which aligns itself with the *U.S. International Traffic in Arms Regulations,* and the fact that Canada closely controls the export of ITAR controlled goods and technology from Canada both clearly demonstrate Canada's on-going bilateral commitment to this important issue.

Canada respectfully requests that proposed regulatory changes consider bilateral, regional and multilateral regulatory cooperation commitments and initiatives.

In summary, Canada supports the U.S. Administration's overall goal of strengthening national security by undertaking reforms that will significantly reduce the regulatory burden and costs associated with no- to low-risk transactions of controlled goods. However, Canada is concerned that the proposed imposition of a new licencing requirement would not achieve this objective by causing unnecessary complications to our highly integrated defence industrial base. For these reasons, we respectfully request that the proposed rules be revised to ensure that under their final form, no item will require an export licence to Canada where none is presently required.

During the regulatory review process, Canadian and U.S. officials have maintained a much appreciated dialogue regarding the proposed changes. We remain available for further cooperation to find mutually beneficial solutions.

Additional technical information and questions regarding our concerns are set out below.

1. Canada understands that under the proposed changes to the Department of State (DOS) International Traffic in Arms Regulations (ITAR) - United States Munitions List (USML) Category XII(c), the items identified to remain on the ITAR are understood to be the "highest sensitivity" and as there are no changes proposed to ITAR s.126.5 – "Canadian Exemption", the items remaining in USML Category XII(c) will remain licence free to Canadian federal, territorial, provincial and municipal departments. It is also understood that exports of Department of Commerce (DOC) controlled night vision / optical sensor items could be exported to Canadian Federal departments in accordance with the DOC "GOV Licence Exception".

   Nonetheless, the "second tier" and "less sensitive" night vision / optical sensor items on the DOC – Export Administration Regulations (EAR) - Commerce Control List (CCL), which for decades have benefited from the DOC licence free status to Canada, will now be subject to new licencing requirements to virtually every entity in Canada including Canadian territorial, provincial and municipal departments. The DOC controlled night vision / optical sensor items have extensive and growing uses in commercial applications, such as industrial process control, gas detection, mapping, home inspection, spectroscopy, semiconductor processing, search and rescue, maritime, security surveillance, firefighting, medical imaging, laboratory research, astronomy and automotive applications.

   What statistics, if any, are available on the volume of trade in commercial night vision / optical sensor items that would be affected by the proposed DOC licencing requirements to Canada?

2. As the items to remain on the DOS ITAR are understood to be of the "highest sensitivity", the second generation *Image Intensifier Tubes (IIT)* that will continue to be controlled on the DOS ITAR (i.e., proposed Category XII (c)(1)(i)) will remain licence free under the DOS ITAR s.126.5 - Canadian Exemption for Category XII(c) to Canadian Registered entities. As this is the case, why are the "less sensitive" and "second tier" items on the DOC CCL being proposed to be licenced to Canada?

3. The DOS ITAR proposed parameters for *IITs* should include an additional control criterion, such as a reliability parameter, to address the environment in which these devices will be required to survive, and thereby clearly distinguish these devices from similar commercially available devices from foreign suppliers such as Hamamatsu, Photonis, Delft Electronic Products and Photek.

4. In the DOC EAR and DOS ITAR currently in-force today there is delineation in the DOS ITAR which establishes which *IITs* are controlled by DOS and those controlled by DOC. However, no such delineation exists in the DOS ITAR for *Focal Plane Arrays* (*FPA*). According to the current DOS ITAR, only those *FPAs* that are specially designed, modified or configured for military use are currently subject to DOS ITAR control. The DOS ITAR

proposed parameters for *FPA*s should include an additional criterion, such as a reliability parameter, to address the environment these devices will be required to survive in, and thereby clearly distinguish these devices from commercially available devices from foreign suppliers such as Sofradir, Selex and Optikos.

5. In order to conduct an impact analysis of the *FPA* proposed regulations on Canada (industry interests and government programs), under what authority (DOC or DOS) are *FPAs* currently controlled, and what is the current technical criterion which differentiates the jurisdiction between DOC and DOS?

6. In the DOC EAR and DOS ITAR currently in-force today there is delineation in the DOS ITAR which establishes which *IITs* are controlled by DOS and those controlled by DOC. However, no such delineation exists in the DOS ITAR for *Electron Multiplication Charge Coupled Devices (EMCCDs).* Although *EMCCDs* are not specifically listed by nomenclature in the DOS ITAR currently in-force today, it is understood that those *EMCCDs* that are deemed to be "other night sighting equipment or systems" that are specially designed, modified or configured for military use are currently subject to DOS ITAR control. The DOS ITAR proposed parameters for *EMCCDs* should include an additional criterion, such as a reliability parameter, to address the environment in which these devices will be required to survive, and thereby clearly distinguish these devices from commercially available devices from foreign suppliers such as E2V and Andor Technologies.

7. In order to conduct an impact analysis of the proposed *EMCCD* regulations on Canada (industry interests and government programs), under what authority (DOC or DOS) are *EMCCDs* currently controlled and what is the current technical criteria which differentiates the jurisdiction between DOC and DOS?

8. The term *"permanent encapsulated sensor assembly"*, is not an industry standard term and, although the proposed regulations provide a subjective definition, how will the exporting community know at what point an item becomes a *"permanent encapsulated sensor assembly"*?

9. For the term *"permanent encapsulated sensor assembly"*, what criteria will be used to gauge what "degree of damage" is sufficient to comply with the requirement?

10. Are there specific examples of *FPAs* that would meet the definition of *"permanent encapsulated sensor assembly"*, and those that would not meet this definition?

11. In the DOC EAR and DOS ITAR currently in-force today there is no definition for *"permanent encapsulated sensor assembly"* to establish what items are controlled by DOS and those controlled by DOC. To conduct an impact analysis of the proposed regulations on Canada (industry interests and government programs), what items are currently considered *"permanent encapsulated sensor assemblies"*, under what authority (DOC or

DOS) are *"permanent encapsulated sensor assemblies"* currently controlled, and what is the current technical criteria which differentiates the jurisdiction between DOC and DOS?

12. Although the term *"camera core"* is used by industry, there are differing opinions amongst manufacturers as to what constitutes a *"camera core"*. How will the public know at what point an item becomes *"camera core"*? Also, it would appear only the proposed DOS ITAR uses the term *"camera core"* and as such, it would be important to clarify what is the equivalent term / area in the proposed DOC EAR.

13. In the proposed DOS ITAR the term *"camera core"* includes additional terms "e.g., modules, engines, kits". Are these terms meant to be equivalent to *"camera core"* and, if so, is there a minimal electronic configuration necessary to establish a "module or kit"?

14. What are the unique characteristics which distinguish a *"fully packaged consumer ready camera"* from a *"camera core"*?

15. In the DOC EAR and DOS ITAR currently in-force today there is no definition for *FPA camera core* to establish what items are controlled by DOS and those controlled by DOC. Although *FPA camera cores* are not specifically listed by nomenclature in the DOS ITAR currently in-force today, it is generally accepted that a *FPA camera core* is the higher level assembly that includes a *FPA* subcomponent, and as such, only those *FPA camera cores* that are specially designed, modified or configured for military use are currently subject to DOS ITAR control.

    In order to conduct an impact analysis of the proposed *FPA camera core* regulations on Canada (industry interests and government programs), what items are currently considered *FPA camera cores*, under what authority (DOC or DOS) are *FPA camera cores* controlled presently and what is the current technical criteria which differentiates the jurisdiction?

16. In the DOC EAR and DOS ITAR currently in-force today there is no definition for *EMCCD camera core* to establish what items are controlled by DOS and those controlled by DOC. Although *EMCCD camera cores* are not specifically listed by nomenclature in the DOS ITAR currently in-force today, it is understood that those *EMCCD camera cores* that are deemed to be specially designed or modified components of "other night sighting equipment or systems" that are specially designed, modified or configured for military use are currently subject to DOS ITAR control.

    In order to conduct an impact analysis of the proposed *EMCCD camera core* regulations on Canada (industry interests and government programs), what items are currently considered *EMCCD camera cores*, under what authority (DOC or DOS) are *EMCCD camera cores* currently controlled and what is the current technical criteria which differentiates the jurisdiction between DOC and DOS?

17. Although the "chapeau" text for the DOC CCL Export Commodity Control Number (ECCN) 6A615 identifies the category as "military", the individual items are not described with the phrase "*are "specially designed" for a USML defence article or a "600 series" ECCN*" as they are specified in other entries in the 600 series. What was the rationale for removing the phrase "*are "specially designed" for a USML defence article or a "600 series" ECCN*"?

18. *Read Out Integrated Circuits (ROIC)*, both off-the-shelf and custom designs, are available from various manufacturers worldwide such as Xenics Infrared Solutions, AIM Intranot-Module, and New Imaging Technologies. The technology necessary to develop and manufacture *ROICs* has been available internationally for many years. The proposed DOC EAR establishes a worldwide control with a presumption of denial. What statistics are available on the volume of trade in commercial *ROICs*, the technology for the development of *ROICs*, and the technology for the production of *ROICs* that would be affected by the proposed DOC licencing requirements to Canada?

HARRIS

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July 1, 2015

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Bureau of Industry and Security
Regulatory Policy Division
1401 Constitution Ave NW
Room 2099B
Washington, D.C. 20130

Ref: ITAR Amendment – Category XII; RIN 1400-AD32 / Public Notice 9110
EAR Amendment – RIN0694-AF75

Harris Corporation is pleased to comment on the proposed revisions to U.S. Munitions List (USML) Category XII and the corresponding controls on the Commerce Control List. Harris appreciates the work that went into crafting the revisions and is encouraged with the continued progress on the Export Control Reform Initiative. However, while the positive listing of items subject to controls, particularly as addressed in the XII(e) enumerated parts and components subparagraphs, is a welcome improvement on the current regulations, we are disappointed that many items with widespread commercial availability in foreign markets will remain controlled under the ITAR, hampering our ability to compete effectively in the global marketplace. We sincerely hope that the proposed changes are a first step towards ultimately relaxing controls on items that no longer merit heightened restrictions for exports to our allies and friendly foreign governments.

ITAR Amendments

Specially Designed Parts and Components

The proposed rule creates an apparent control inversion between the generic specially designed "catch-all" language within the proposed USML XII(c)(1) and XII(c)(13) entries and the specifically enumerated parts, components and other commodities included in the proposed USML XII (e)(2)(i) – (vii) and USML XII(e)(9), and (12) entries.

The IIT parts and components enumerated within XII (e)(2) represent the most critical and sensitive parts and components of an image intensifier tube due to their unique contributions to military night vision systems utilizing IIT. The listing of those parts and components helpfully adds specific performance and quantitative criteria which provide a bright line for quick identification of the parts and components intended to be controlled.

However, the proposed USML XII(c)(1) entry, which describes the IIT's to which XII (e)(2) applies, contains its own specially designed parts and components "catch-all" clause. This results in an apparent logical paradox that subjects non-enumerated specially designed parts and components excluded from the scope of USML XII (e) (2) to higher level controls as Significant Military Equipment (SME), as they would necessarily be captured within USML XII(c)(1) by default. For example, under the proposed rule, a specially designed sub component of a XII(e)(2)(vi) miniature autogated power supply would be controlled under XII(c)(1) as SME, representing a higher level of control for the lower level part than the completed autogated power supply component .

To address this issue, Harris recommends that the generic, specially designed parts and components "catch-all" language be removed from USML XII(c)(1) and that equivalent language be added to USML XII(e)(2) as follows:

> *(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:
>
> (1) Image intensifier tubes (IITs) having a peak response within the wavelength range exceeding 400 nm but not exceeding 2,050 nm and incorporating either a microchannel plate described in paragraph (e)(2)(i) of this category or electron sensing device described in paragraph (e)(2)(iv) of this category, as follows: [~~**and specially designed parts and components therefor:**~~]
>
> *****
>
> (e) Parts, components, accessories, attachments, and associated equipment as follows:
>
> *****
> (2) Image intensifier tube (IIT) parts and components as follows:
>
> *****
> **(viii) Parts and components specially designed for IIT's identified in USML XII(c)(1).**

The proposed revisions recommended above additionally ensure alignment with language contained within **Note 2 to paragraph (f)**, which identifies IITs and their parts and components as being controlled within two distinct entries.

> "...*IITs controlled in paragraph (c)(1)* of this category and their *parts and components controlled in paragraph (e)(2)* of this category..." [emphasis added]

The proposed entries for USML XII(c)(12) and (13) relating to binoculars, goggles, and other imaging systems and infrared imaging cores also include "specially designed" catch all clauses which create a similar control inversion problem (SME vs. non-SME) with respect to the parts and components specifically identified in proposed USML XII(e)(9), and (12).

Harris recommends that the specially designed language of USML XII(c)(12) and (13) likewise be omitted, and that language with similar effect be inserted as a new entry into the text of USML XII(e)(9), and (12) to ensure that parts and components intended to be "caught" under USML XII(c)(12) and (13) are identified and proportionally controlled, as follows:

> *(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:

****

(12) Infrared imaging camera cores (e.g., modules, engines, kits), [~~**and specially designed electronics and optics therefor,**~~] having any of the following:

(13) Binoculars, bioculars, monoculars, goggles, or head or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate any of the following, [~~**and specially designed electronics, optics, and displays therefor:**~~]

*****

(e) Parts, components, accessories, attachments, and associated equipment as follows:

*****

(9) **Optics, i**nfrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category;

*****

(12) **Displays (including near-to-eye displays)** specially designed for articles controlled in this category;

Harris notes that its recommended revision of USML XII(e)(12) does not overlap with the current proposed entry at USML XII(c)(18), "Near to eye display *systems or equipment…*" [emphasis added], as the former is obviously intended to encompass the display component, whereas the latter addresses completed systems or equipment, more logically subject to control as SME.

Note to paragraph A of note 2 to paragraph (f)

After careful study of this note, Harris concludes that the listed technical data exclusion categories are limited exclusively to data and classes of activity relating to IRFPAs rather than broadly to all the items discussed within Note 2 to paragraph (f), e.g. lasers, ITTs, etc. If the desired intent is properly understood, Harris suggests the following revision to avoid the potential for ambiguity:

Current proposed rule wording:

Note to paragraph A of Note 2 to paragraph (f): Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.

Recommended revision:

Note to paragraph A of Note 2 to paragraph (f): Technical data **directly related to IRFPAs** does not include information ~~**directly related to**~~ **on** basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.

EAR Amendments

It appears that EAR 742.6(a)(8)(ii) will require that a license be obtained to export or re-export to Canada, items subject to control under ECCN 6A002 for Regional Stability (RS) purposes.

The licensing requirement would be a departure from the way more sensitive items are controlled under U.S. Munitions List (USML) Category XII(c). By way of example, if a Generation 3 image intensifier tube (IIT) is incorporated into a commercial direct view night vision system, the system would be controlled under ECCN 6A002.c, as described in Note 2 to paragraph XII(c) on the USML. If the same IIT were incorporated into a night vision device specially designed for the military, it would be controlled under USML XII(c)(13). The new RS control would require a license to Canada for the 6A002.c item, while by contrast the ITAR exemption at 22 CFR 126.5(b) and (d) would continue to authorize exports, re-exports, and retransfers of XII(c)(13) items to certain end users in Canada.

At a high level, following is a summary of the ITAR exemption as it applies to USML XII(c) items:

- Canadian government entities (e.g., federal , provincial, territorial, or municipal) are eligible to receive: 1st- and 2nd-generation image intensification tubes and night sighting equipment, 3rd-generation end items
- Canadian-registered persons are eligible to receive: 1st- and 2nd-generation image intensification tubes and night sighting equipment

It does not appear that 6A002.c items would be eligible for EAR exceptions STA or GOV for exports to the end users identified in the ITAR exemption.

Harris respectfully requests that the Commerce Department consider the implementation of EAR licensing exception authority for 6A002 items similar to the Canadian license exemption authority available for items subject to control under USML XII(c).

Sincerely,

Mary C. Menz
Vice President, Corporate Trade Compliance
Harris Corporation

cc: Ron Roos
Deputy General Counsel
Exelis, Inc.

Honeywell

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July 1, 2015

Department of State
Bureau of Political-Military Affairs
Department of Defense Trade Controls
2401 E Street, N.W.
12th Floor, SA-1
Washington, D.C. 20522

ATTN: Mr. C. Edward Peartree, Director, Defense Trade Controls Policy

SUBJECT: Honeywell Response to Proposed USML Category XII Changes

Reference: Federal Register Vol. 80, No. 86, amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, published May 5, 2015.

Dear Mr. Peartree:

Honeywell International Inc. provides the following comments with regard to the proposed changes to ITAR Category XII, and specifically to the proposed language in Category XII(d) which covers inertial systems and components.

The proposed rule as written appears to introduce the potential for significant unintended consequences, where currently certain Commerce Control List (CCL) sensors (accelerometers and gyros) that are incorporated into FAA civil certified systems/aircraft and used for other commercial applications would become ITAR controlled. This is based, in part, on the fact that the proposed performance criteria and testing protocols for accelerometers and gyros differs substantially from the current criteria established in the U.S. Department of Defense Inertial Navigation System Policy (DOD INS Policy) of 2010.

Honeywell appreciates the effort to introduce a proposed rule that more clearly defines specific items that would be subject to the ITAR. The following comments outline Honeywell's concerns with the proposed rule.

Proposed Control Language for Gyros and Accelerometers:

The language in "Category XII(d)(2) Accelerometers" would now define USML accelerometers as those accelerometers having a bias stability of better than 20 micro-g's or scale factor stability of better than 20 parts per million. The term "stability" is not defined in the ITAR text, but does have definition in the U.S. Department of Commerce regulations, and by the IEEE, and involves performance measurement during fixed operating conditions. Under these benign conditions, the types of accelerometers that are in use in commercial inertial systems exhibit very good bias and scale factor performance. As a result, Honeywell believes that a majority of accelerometers currently on the CCL would be captured by the USML with this proposed language.

The language in "Category XII(d)(3) Gyroscopes" would now define USML gyros as those gyros that have an Angle Random Walk (ARW) better than 0.00125 degree per square root hour or that have a bias stability better than 0.0015 degrees per hour. The ARW control is a well understood measurement and a reasonable choice for performance control. However, there are commercial inertial systems in civil aircraft that have ARW values better than this level. Honeywell believes

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the control level should be no larger than 0.0010 degrees per square root hour to avoid controlling civil aircraft systems. The larger problem is with the inclusion of bias stability as a control, which will cause most civil aircraft and other ring laser gyro based commercial inertial systems to be captured under the munitions list, which we do not believe was the intent of the control.

Honeywell believes the more effective method for assessing gyro and accelerometer performance is aligned with the U.S. Department of Defense Inertial Navigation System Policy (DOD INS Policy) of 2010, which differentiates systems that are effective in higher performance military applications from those that are not. The measurements in the DOD INS Policy reflect gyro and accelerometer performance allowing for inclusion of measurement of bias over the operating conditions that the system must perform in, makes clear that the performance applies to product lines, not individual accelerometers and gyros, and does not depend on the "stability" term.

Additional comments:

1) The addition of "MT" in the proposed language for XII(d)(2) and XII(d)(3) is confusing. Adding (MT) reasons for control on the USML implies that performance at these levels places the item in XII(d), while export classifications 7A101 and 7A102 in the U.S. Commerce Department Export Administration Regulations are actually the controls implementing these particular Missile Technology Control Regime agreements.

2) Language in the proposed rule references VIII(e). This reference should be removed if it is the Department of State's intent to move VIII(e) controlled inertial devices to the new controls in XII(d) and 7A611.a of the EAR.

3) Honeywell recommends adding the term "specially designed" to Cat. XII(d) for inertial components (gyros and accelerometers). This would ensure that only sensors "specially designed" with values described in Cat. XII(d) are subject to control under the USML.

4) XII(d)(1)(iii) catches any guidance or navigation system (including units such as IMU, AHRS) that are specified to function at linear acceleration levels exceeding 25g. Honeywell believes there are commercial systems that would be caught by this control language that are not high performance and are designed for commercial use.

5) XII(d)(2) for accelerometers applies an "OR" term such that bias stability "or" scale factor stability will cause an accelerometer to be captured. The DOD INS Policy requires specific levels of bias "AND" scale factor performance, which avoids capturing accelerometers currently used in commercial aircraft.

If you have any questions or would like to discuss any of the comments provided above, feel free to contact the undersigned at 202-662-2641 or via e-mail at dale.rill@honeywell.com.

Sincerely,

Michael Scoggin for

Dale Rill
Director, Export Control and Compliance
Honeywell International Inc.

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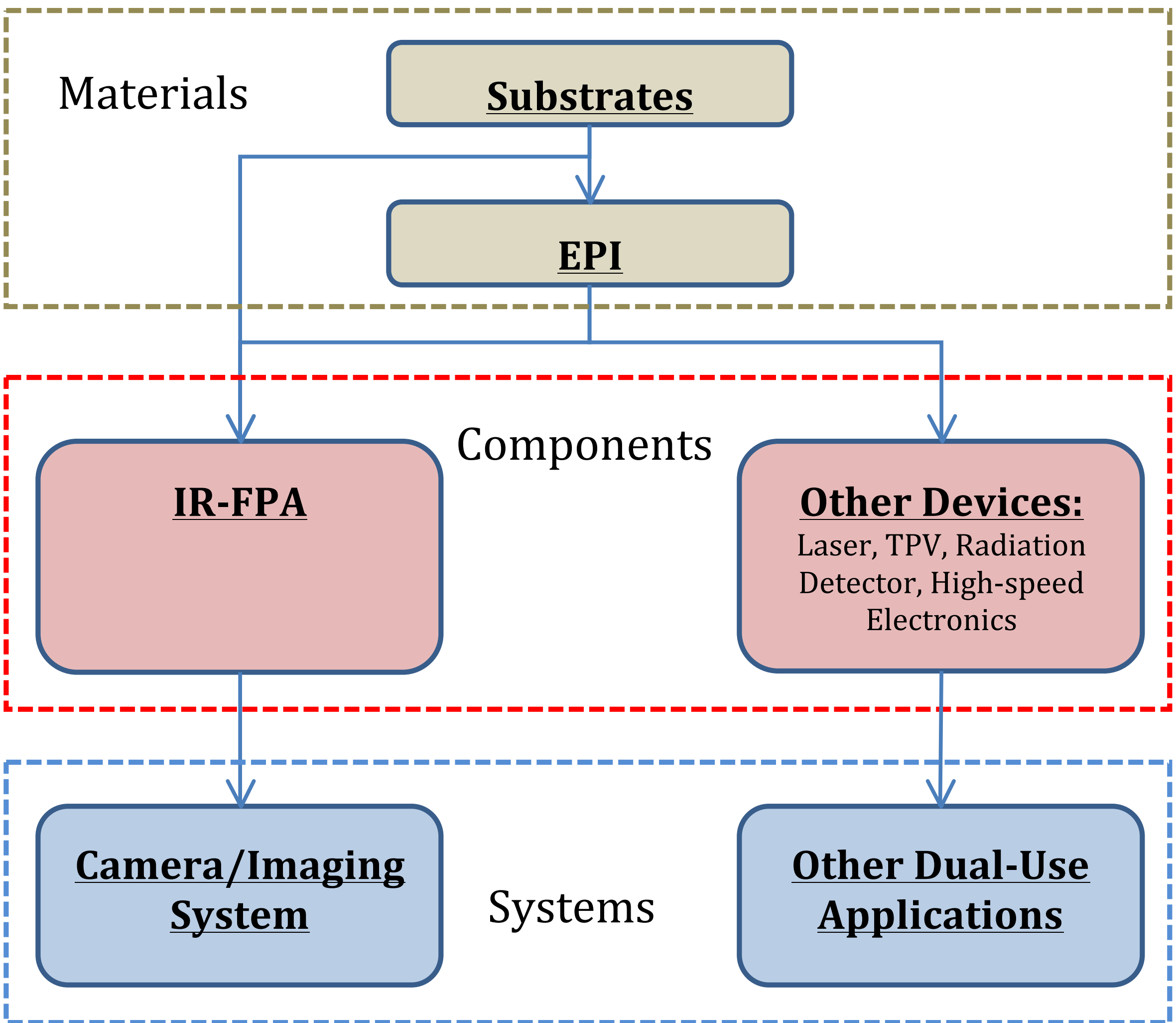
Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

Intelligent Epitaxy Technology, Inc. (IET) was first established in January 1999 in Richardson, Texas to supply epitaxy-based compound semiconductor epi-wafers to the electronics and optoelectronics industries. This covers epitaxy materials grown on GaAs, InP, GaSb, InSb and Si. In recent years, IET has also expanded the business vertically into specialty substrate area such as GaSb as well. Our primary business is the development and production of starting materials which include specialty semiconductor substrates and epitaxy materials as shown in the supply chain diagram below.



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In the current re-write of USML Category XII, may of our key products would be controlled under paragraphs c(2) and e(3) specifically for IR FPAs and their components. These entries would control substrate/epi materials products produced and sold by IET. We believe the current language for these entries would be overly restrictive, controlling products with dual-use applications while failing to achieve the goals of the ECR guideline. More specifically, it is our belief that the current language is trying to protect too much, which will diminish the government's ability to focus efforts on the most critical national security priorities. Furthermore, these restrictions will end up destroying the US manufacturability and competitiveness that the USML code is hoping to protect. Foreign completion will end up gaining market share and eventually force US manufacturing base to exit these markets all together.

I. Substrate

During the past several years, IET has established a domestic GaSb wafer manufacturing capability in the US with funding support from the DOD. Right now, IET is offering 2", 3" and 4" sizes commercially and with larger sizes in development. This is to support internal use, as well as, external commercial customers. The primary market for these GaSb substrates are for epitaxy growth of IR detector materials. Under the current language proposed for paragraphs c(2) and e(3), these substrates will be under ITAR control. However, GaSb substrates are also in non-military commercial applications as well. Not all of the non-military applications are mature; some are still under development.

Examples of non-military end product applications based on IR-FPAs include:

- Personal/industrial security for persistent surveillance
- Search and rescue
- Industrial/construction heat detection and failure analysis
- Gas leak detection such as CO2 or SF6 (Ex. FLIR GF300/320 http://www.flir.com/ogi/display/?id=55671 [attachment 01]) (Foreign ex. IR Nova: http://www.ir-nova.se/applications/gas-detectionindustrial/ [attachment 02])
- Medical research such as cancer/tumor detection (Ex. Skinfrared [attachment 03] http://skinfrared.com/research-divisions/infrared-imaging-division/)

In addition, there are non-FPA applications such as:

- Thermal photovoltaic (TPV),
- 2-4 um lasers such as Interband Cascade Laser (ICL [attachment 04] http://nanoplus.com/en/products/distributed-feedback-lasers/distributed-feedback-lasers-3000-nm-6000-nm/) and Type I bulk (http://brolis-semicon.com)

Furthermore, many of these controlled IR FPA products and their components are commercially available abroad from foreign companies such as SCD, Thales, BAE, Selex and IR-NOVA.

In note 2 to paragraph (c) uses the technical threshold of 640 detector elements. While that may be an acceptable current threshold indicating military use, it may not remain so in the future. There should be a mechanism in-place to amend this requirement as the technology landscape changes.

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The trend over the past years has been for increasingly larger wafer sizes and more dual-use applications. For example, GaSb substrates with up to 4" in diameter are currently available from foreign supplier with Wafer Tech (a UK company) being the world leader—not a US company. Wafer Tech has recently demonstrated the capability to manufacture 7" diameter at the 2015 SPIE-DSS Conference in Baltimore (see attachment 05). The industry will continue to move towards larger detectors, including for dual-use applications.

From a broader perspective, we believe restricting IR FPA substrates would prevent US companies from effectively competing in the international marketplace while not effectively protecting US military interests. Unfortunately, the US isn't necessarily ahead of all foreign competitors especially in market share. As an example, for CdZnTe substrates, Nikko-Japan Energy is the industry leader. Additionally, these controls will encourage foreign competition while stifling the domestic semiconductor industry. For instance, there is no longer a domestic US manufacturing base for GaAs or InP substrate anymore. AXT (www.axt.com), a public US company that designs, develops, manufactures and distributes high-performance compound semiconductor substrates, has moved all of its manufacturing to China due to more competitive manufacturing cost structure. AXT was originally started with Vertical Gradient Freeze crystal pulling technology licensed from AT&T Bell Labs. AXT was also funded by Title III money.

The semiconductor industry is mature and extremely competitive. US export controls burdens US semiconductor companies with more conditions on foreign sales and longer and less predictable waiting periods for license approval than faced by foreign based companies. The extended waiting time and added complexity needed for responding to potential customers can impact the competitiveness of US companies even if export licenses are not denied.

II. Epi Materials

The development of improved epitaxial wafers (Epi-wafers) requires significant investments in research and development along with manufacturing infrastructure by Epi-wafer suppliers. Our foreign competitors have larger market share positions in worldwide epi-wafer production. For example, the 2014 IQE annual reports states that UK based IQE has 48% of the worldwide market share of for compound semiconductor wafers.[1] Taiwan based Visual Photonics Epitaxy (VPEC) and Landmark Optoelectronics Corporation has 18% and 10% market shares respectively. In contrast, smaller player such as IET and Epiworks have only about 5% worldwide market share apiece. The small market share positions of US based companies make it difficult for these companies to invest in the infrastructure needed to compete with these well-established foreign competitors. Restrictive export controls will further exacerbate the competitive challenges faced by US companies in this industry. For a list of non-US sources with epi capabilities, please see the attached spreadsheet (attachment 06).

An example of a foreign HOT-MW FPA/camera product that exceeds USML technical parameters in note 2 to paragraph (c) is the SCD HOT Hercules with a 1280x1024 FPA format with 15 micron pitch (see attachment 07 or http://www.scd.co.il/HOT-HERCULES-1280-15). SCD produces its own epi in Israel. In fact, some of the initial development of this work was funded by DARPA (http://www.semiconductor-today.com/news_items/2008/AUGUST/SCD_130808.htm). As

[1] IQE, "2014 Annual Report and Financial Statements", IQE Website, http://www.iqep.com/media/113503/IQE2014AnnualReport_Web.pdf.

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example if we are restricted to supply epi wafers to them based on their own IP then this will likely encourage them to develop their own additional manufacturing capability themselves without further reliance on US manufacturing capability.

III. Conclusions

We conclude that the current language for the above mentioned entries would be overly restrictive, controlling products with dual-use applications while failing to achieve the goals of the ECR guideline. Furthermore, it is our belief that the current language is trying to protect too much, which will diminish the government's ability to focus efforts on the most critical national security priorities. IET also supports the potential conclusion that the USML should align with the Wassenaar Munitions List.

If you require any further information, please contact me at 972-814-6050 or via email at pinsu@intelliepi.com.

Sincerely,

Paul Pinsukanjana

Paul Pinsukanjana, Ph.D.
VP of Technology/Business Development
Intelligent Epitaxy Technology, Inc.

FLIR GF300/320 Infrared Cameras

For Gas Leak Detection and Electrical Inspections

The FLIR GF300/320 infrared camera is a preventative maintenance solution to spot leaks in piping, flanges and connections in petrochemical operations. The infrared camera can rapidly scan large areas and pinpoint leaks in real time. It is ideal for monitoring plants that are difficult to reach with contact measurement tools.

Literally thousands of components can be scanned per shift without the need to interrupt the process. It reduces repair downtime and provides verification of the process. Above all it is exceptionally safe, allowing potentially dangerous leaks to be monitored from several meters away. FLIR GF300/320 will significantly improve your work safety, environmental and regulatory compliance, not to mention helping to improve the bottom line by finding leaks that essentially decrease profits. The new GF300/320 now embeds GPS data into the image allowing workers to pinpoint the location of the leak or hot spot.

Key Features

- Visualize gas leaks in real time
- Fully calibrated for temperature measurement applications
- Embedded GPS data in reporting
- Inspect without interruption of process
- Considerably reduce inspection time
- Trace leaks to source
- Spot leaks close by or meters away
- Verification of repair

Makes Reporting Easy

Images from FLIR GF-Series infrared cameras are recordable to any off-the-shelf video recorder for easy archiving and documentation.

Rotatable flip out screen makes it possible to inspect hard to reach places

Scan large areas and pinpoint leaks in real time

/?id=62960)

FLIR LS-Series (/law-enforcement/display/?id=57065)
FLIR H-Series (/law-enforcement/display/?id=50691)
FLIR BHS-Series (/law-enforcement/display/?id=50843)

(/threatdetection/display/?id=63346)
Explosives Detection (/threatdetection/display/?id=65350)

GAS DETECTION SYSTEMS (/ogi/content/?id=66693)

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FLIR GF306 (/ogi/display/?id=55666)
FLIR GF309 (/ogi/display/?id=55667)
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Laser Components & Systems (/cores/display/?id=52626)
Pan-Tilt Systems (/mcs/view/?id=53484)

AUTOMATION (/automation/content/?id=65833)

FLIR Compact A-Series (/automation/display/?id=56341)
FLIR A300 / A310 (/automation/display/?id=41099)
FLIR A310pt / A310f (/automation/display/?id=56385)
FLIR A310ex (/automation/display/?id=63398)
FLIR A315 / A615 (/automation/display/?id=41330)
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Sixth Sense™ (http://www.flir.com)

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for advanced imaging applications

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- Search and Rescue
- Process control and gas detection
- R&D and Space

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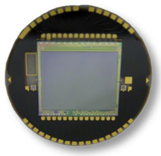
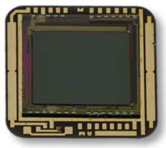
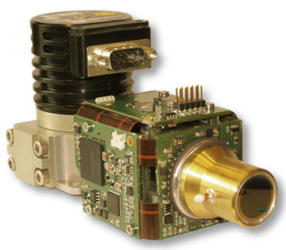
- MWIR and LWIR products
- Quantum Well and T2SL based detectors
- Various formats and cooling options
- Easy-to-use proximity electronics
- Small and versatile designs





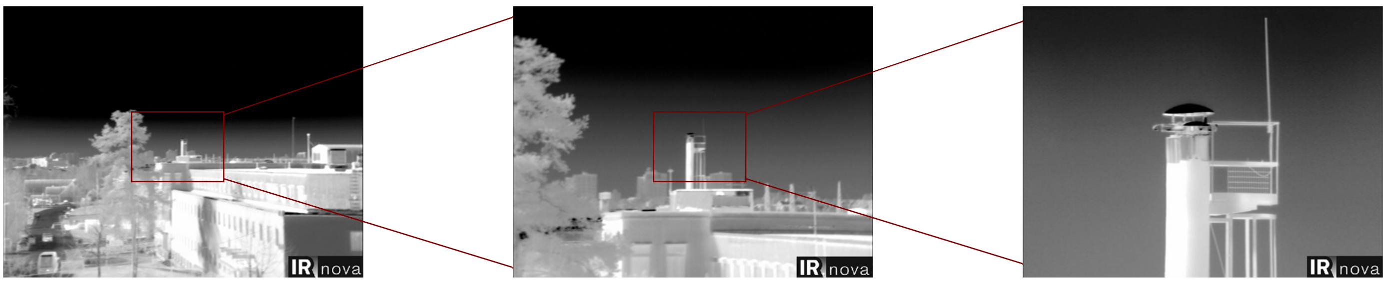
DETECTOR OPTIONS

Type	Resolution	Pitch
MWIR / T2SL	640 x 512	15 µm
LWIR / QWIP	640 x 512	25 µm
LWIR / QWIP	640 x 480	25 µm
LWIR / QWIP	384 x 288	25 µm
LWIR / QWIP	320 x 256	30 µm
SF_6 / QWIP (10.55)	320 x 256	30 µm
MWIR / T2SL	320 x 256	30 µm
CH_4 / T2SL (3.30)	320 x 256	30 µm



IDCA OPTIONS

Type	Features
Split cooler	Long life time Low noise and vibration Separated heat removal
Integral cooler	High efficiency Compact Low weight



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The Infrared Market

The infrared imaging business comprises two main markets: Lower cost, higher volume devices, and high cost, low volume devices.

The first category is most often represented by bolometers, which operate at room temperature and provide relatively simple information. The end user of the bolometer device is often a consumer, for instance in the case of a vehicle with a thermal imager on the dashboard to aide in identifying road hazards. By 2017, these devices are projected to cost less than $1,000, similar to the cost of a GPS unit a decade ago.

Bolometer devices are not sufficiently sensitive for the second category of infrared imaging. The second category includes a wide variety of uses in highly specialized industrial, military, and medical devices.

The sensors we are developing are faster, cooled, Type II Superlattice detectors, purpose built for their applications. Our devices are uniquely suited to the particular situation for which we manufacture them, and fine tuned to generate the necessary specific imaging results.

Strategic Partners

Raytheon

Our biggest strategic partner is Raytheon Vision Systems, but we work closely with a variety of partners in industrial consortium. We are also funded through a combination of government and private sources.

Our Technology

We are involved with the development of next-gen infrared imagers and can fabricate test diodes with 320×256 focal plane arrays as well as 640×512 fpa imagers using Type II strained layer superlattices.

This technology has demonstrated dramatic improvement in device performance in the past few years.

The SLS technology consists of hundreds of periods of very thin layers of two different semiconductors. Specifically, InAs and GaSb are deposited one after the other. This idea was first proposed by Nobel Laureate, Leo Esaki, in the early 70's. However, the technology did not exist to actually realize these highly precise nanostructures in the laboratory.

In the past decade, there has been a dramatic improvement in the performance of infrared imagers based on these superlattices. The superlattices have been identified as a leading technology for the development of next generation infrared imagers by the Department of Defense. They have a large quantum efficiency and high sensitivity in the mid wave infrared (3-5µm) and long wave infrared (8-12µm).

We have access to "Epi to Camera" research for realizing these detector technologies. This involves heterostructure design and engineering, crystal growth using molecular beam epitaxy, materials characterization, single and focal plane array fabrication, hybridization and radiometric characterization as shown.

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Vision and Mission

Vision: Engineering the infrared spectrum for medical solutions.

Mission: To develop a low cost, portable, high performance, infrared imaging system for non-invasive medical diagnostics.

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- job posting: Full Time Test Engineer (salary dependent upon experience)
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To Top

Distributed Feedback Lasers: 3000 nm - 6000 nm

nanoplus offers DFB interband cascade lasers at any wavelength between 3000 nm and 6000 nm.

Prism Award Winners 2012

PRISM AWARDS WINNER

nanoplus DFB interband cascade lasers (ICLs) won the "Prism Award for Green Photonics and Sustainable Energy" in 2012. They cover the entire wavelength range from 3000 nm to 6000 nm. Many prominent gas species have their strongest absorption features in this window. They are now accessible for tunable diode laser spectroscopy in industry and research. SPIE and Photonics Media honored the laser development in a ceremony during Photonics West in San Francisco.

Key features of nanoplus DFB interband cascade lasers

- monomode
- continuous wave
- room temperature
- low power consumption
- tunable
- custom wavelengths

Why choose nanoplus DFB interband cascade lasers

- stable longitudinal and transversal single mode emission
- precise selection of target wavelength
- narrow laser line width
- mode-hop-free wavelength tunability
- fast wavelength tuning
- typically > 5 mW output power
- small size
- easy usability
- high efficiency
- long-term stability

For more than 15 years nanoplus has been the technology leader for lasers in gas sensing. We produce lasers at large scale at our own fabrication sites in Gerbrunn and Meiningen. nanoplus cooperates with the leading system integrators in the TDLAS based analyzer industry. More than 15,000 installations worldwide prove the reliability of nanoplus lasers.

Quick description of nanoplus DFB laser technology

nanoplus uses a unique and patented technology for DFB laser manufacturing. We apply a lateral metal grating along the ridge waveguide, which is independent of the material system. Read more about our patented distributed feedback technology.

Related information for nanoplus DFB interband cascade lasers between 3000 nm and 6000 nm

Specifications | Mountings & Accessories | Applications | Papers & Links

The following table summarizes the typical DFB laser specifications in the 3000 nm to 6000 nm range:

parameters	symbol	unit	minimum	typical	maximum
wavelength precision	δ	nm		0.1	
optical output power	P_{out}	mW		> 1	

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- nanoplus ESD ThermalManagement.pdf

temperature tuning coefficient	C_T	nm / K	0.3
reverse voltage	U_r	V	7
slope efficiency	e	mW / mA	0.06
side mode suppression ratio	SMSR	dB	> 32
slow axis (FWHM)		degrees	35
fast axis (FWHM)		degrees	55
storage temperature	T_S	°C	+20
operational temperature at case	T_C	°C	+20

nanoplus DFB lasers show outstanding spectral, tuning and electrical properties. They are demonstrated in figures 1 - 3. Click on the graphics to enlarge.

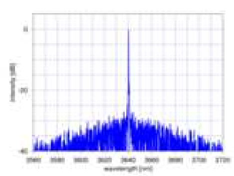

Figure 1: Spectrum of nanoplus 3640 nm DFB interband cascade laser

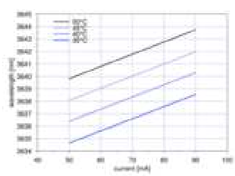

Figure 2: Mode hop free tuning of nanoplus 3640 nm DFB interband cascade laser

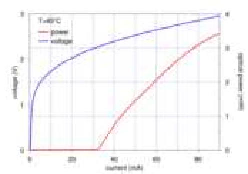

Figure 3: Typical power, voltage and current characteristics of nanoplus 3640 nm DFB interband cascade laser

If you are uncertain whether you require a DFB laser, compare the specifications with our Fabry Perot Lasers or contact us.

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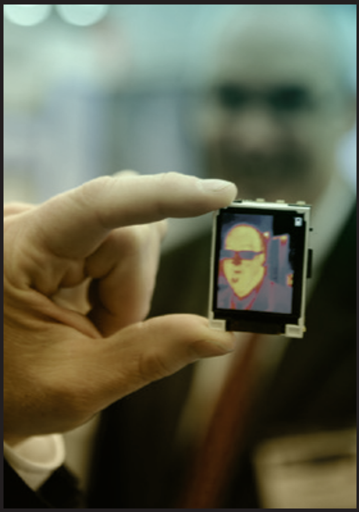
Plenary Presentation

Monday 20 April 2015 · 5:00 to 6:00 pm

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

See page 7 for more information



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- Ocean Sensing
- Sensing for Agriculture and Food/Water Safety

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TECHNICAL/INDUSTRY EVENTS

Connect with peers and make new connections at a variety of technical and networking sessions

Monday 20 April.

SPIE Fellows Luncheon

12:00 to 1:30 pm

All SPIE Fellows are invited to join your colleagues for this fifth annual SPIE-hosted luncheon. The new Defense, Security, and Sensing Fellows will be introduced and receive their Fellow plaques. Please join us for this informal gathering and a chance to interact with other Fellows.

Fellows planning to attend are asked to RSVP to Brent Johnson.

Fellows Luncheon Presentation: **Dr. Michael Eismann,** The U.S. Air Force Research Laboratory

PANEL DISCUSSION

Issues and Challenges of the Applications of Context to Enhance Information Fusion

Conf. 9474 · 1:15 to 4:45 pm

Panel Organizers: **Erik Blasch,** Air Force Research Lab. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA)

Panel Moderators: **Ivan Kadar,** Interlink Sciences Systems, Inc. (USA); **Chee-Yee Chong,** Independent Consultant (USA)

Panel Members: **Erik Blasch,** Air Force Research Lab. (USA); **Alex L. Chan,** U.S. Army Research Lab. (USA); **Chee-Yee Chong,** Independent Consultant (USA); **Laurie H. Fenstermacher,** Air Force Research Lab. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Ronald P. S. Mahler,** Consultant (USA); **Alan N. Steinberg,** Independent Consultant (USA); **Paul Tandy,** Defense Threat Reduction Agency (USA); **Shanchieh Jay Yang,** Rochester Institute of Technology (USA)

For a given application contextual information represents prior domain knowledge about the setting of the scenario/process to commence. The contextual knowledge can be acquired from prior (historical) experience, provided by external sources (e.g., user), learned from process experience, e.g., context awareness, prediction and search; and can be updated/corrected if changes are detected, e.g., by machine learning.

Context is present in all aspects of processing and interpreting information, situation, data, text, imagery, target tracking/identification, web-analytics, and intelligence systems outputs, that is, in all aspects/levels of information fusion (IF). Context is a multi-faceted entity, and can represent a setting for the assessment/interpretation of an event, scene, presence, situation, condition, constraint, influence, and many other entities clearly scenario/application dependent. There is context within context. Furthermore, context is not a static entity and can change over time (e.g., operating conditions, environment, geography, weather, seasons, roads, traffic, attitudes, behavior, preferences) affecting the performance of a given application if not managed and taken into account. Therefore, it is important to incorporate contextual information at the outset in all IF levels and associated systems designs in order to enhance the performance of the overall IF system and the on-going application.

For example in tracking application one can describe at least five contextual categories: (1) domain knowledge from a user to aid the information fusion process through selection, cueing, and analysis, (2) environment-to-hardware processing for sensor management, (3) known distribution of entities for situation/threat assessment, (4) historical traffic behavior for situation awareness patterns of life (POL), and (5) road information for target tracking and identification. Appropriate characterization and representation of contextual information is needed for future high-level information fusion systems design to take advantage of the large data content available for a priori knowledge target tracking algorithm construction, implementation, and application.

The objective of this panel is to bring to the attention of the fusion community the importance of the application of contextual knowledge to enhance IF, highlighting issues, illustrating potential approaches and addressing challenges. A number of invited experts will discuss challenges of the fusion process and research to address these challenges. The panelists will illustrate parts of the above mentioned areas over different applications and address all levels of information fusion. Conceptual and real-world related examples associated with the use of context to enhance IF will be used by the panel to highlight impending issues and challenges.

PANEL DISCUSSION

Metrology for Additive Manufacturing

Conf. 9489 · 2:10 to 3:30 pm

Moderator: **Edward W. (Ted) Reutzel,** Applied Research Lab. (USA)

Panelists: **Doug Rhoda,** Wolf Robotics (USA), **Radovan Kovacevic,** Southern Methodist Univ. (USA), **Shawn Kelly,** Edison Welding Institute (USA), **Jyoti Mazumder,** Univ. of Michigan (USA), **Edward Herderick,** GE Corporate (USA)

Process sensing plays an increasingly important role in a wide range of manufacturing processes, both to enable rapid assessment of quality and to provide critical data to real time control systems. Advanced sensors and exploding computational capability afford (i) practitioners, (ii) equipment suppliers, and (iii) researchers unprecedented opportunities to collect and analyze complex sensor data to ensure quality product.

This panel discussion brings together leaders representing these three communities to discuss sensing and control for laser, electron beam, and arc-based welding, metal deposition, and additive manufacturing processes. The current state-of-the-art, current research, issues, and opportunities will be explored.

The Infrared Applications: ThermoSense XXXVII Vendor Session

Conf. 9485 · 1:00 to 5:00 pm

Moderators: **Andrés E. Rozlosnik,** SI Termografia Infrarroja (Argentina), and **Herb Kaplan,** Honeyhill Technical Co. (USA)

The Infrared Applications: ThermoSense XXXVII Vendor Session will be held on Monday afternoon, 20 April 2015 as part of the SPIE DSS 2015 Conference in Baltimore. The session will feature brief presentations from hardware and software vendors whose product lines impact thermal imaging applications. Unlike the technical sessions, there are no "commercial content" restrictions in these presentations.

This event allows vendors to showcase new products on display at this year's exhibit, and provides attendees with an advance glimpse of "what's new" in thermal imaging applications.

If you are interested in participating or have any questions, please contact: Vendors Session 2015 Moderators Herb Kaplan, or Andres Rozlosnik: hkaplan@earthlink.net or aer@termografia.com

Plenary Presentation

5:00 to 6:00 pm

Alan R. Shaffer

Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Mr. Shaffer is currently serving as the Acting Assistant Secretary of Defense Research and Engineering. He also serves as the Principal Deputy Assistant Secretary of Defense Research and Engineering, a position he has held since 2007. In this position, Mr. Shaffer is responsible for formulating, planning, and reviewing the DoD Research, Development, Test, and Evaluation (RDT&E) programs, plans, strategy, priorities, and execution of the DoD RDT&E budget that totals roughly $25 billion per year. He has also serviced twice as the Acting Director of Defense Research and Engineering, currently titled the Assistant Secretary of Defense (Research and Engineering), first from 2007 to 2009 and then again from 2012 to 2013. Additionally, in 2009, he was appointed as the first Director, Operational Energy, Plans and Programs (Acting). Mr. Shaffer has also served as the Executive Director for several senior DoD Task Forces. In 2005 he served as the Executive Director for the Technical Joint Cross Service Group that reviewed the 300 DoD research, acquisition and test activities during the Base Realignment and Closure activity. In 2007, he was the Executive Director for the DoD Energy Security Task Force, which led to the establishment of a congressionally confirmed position to focus on DoD operational energy use. Most recently, he served as the Executive Director of the Mine Resistant Ambush Protection (MRAP) Task Force, which he was responsible for fielding 27,000 MRAPs.

Prior to entering the federal government, Mr. Shaffer served a 24-year United States Air Force career with assignments in weather, intelligence, acquisition oversight, and programming.

Welcome Reception

6:15 to 7:45 pm

All-Symposium Welcome Reception
Maryland Science Center

All attendees are invited. Relax, socialize, and enjoy the refreshments and all that the museum has to offer. Located in Baltimore's Inner Harbor, it is a short walk from the convention center and one of the harbor's main attractions, serving more than half a million visitors per year. Please remember to wear your registration badge. Dress is casual.

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

Tuesday 21 April.

Lunch with the Experts - A Student Networking Event

12:30 to 1:30 pm
Open to Student Attendees

Enjoy a casual meal with colleagues at this engaging networking opportunity. Hosted by SPIE Student Services, this event features experts willing to share their experience and wisdom on career paths in optics and photonics.

PANEL DISCUSSION

Anticipative Computing for Autonomous Sensing and Analytics: What is over the horizon?

Conf. 9473 · 1:20 to 3:00 pm

Moderator: **Kannappan Palaniappan,** Univ. of Missouri-Columbus (USA)

With the recent advances in novel sensors and agile platforms for airborne and satellite-based urban mapping, deep learning, neuromorphic architectures, power efficient computing, encrypted sensor networks and highly compact cloud-based storage, the prospect for persistent sensing without sustained continuous reach-back seems to be within reach. Are we ready for autonomy at the edge? What is the critical role of anticipative computing, global autonomous mapping and decision making? One can expect the development of fluid evasive behavior by mobile targets in this context? How should autonomy tasks be formulated in such scenarios? What context-based and scene adaptive video processing, bi-directional information flows and video analytic elements with learning do we want to provide to enable anticipative analytics at the edge? What are the benefits we want autonomous computing to provide to systems operating at the edge?

Charting a Course in the Photonics Industry

3:00 to 5:00 pm

Shape yourself for a future in photonics. This speaker series will help you explore potential career pathways in the world of photonics outside of academia. Get solid advice on how you can translate your knowledge, abilities, and interests into meaningful work. Whether you work for an existing company or start your own, getting a clear picture of the options from experienced leaders will help you better manage your career trajectory. The series will conclude with a question-and-answer session (with all speakers) and a light refreshment reception.

Next Generation Analytics Panel of Experts Discussion

Conf. 9499 · 3:30 to 5:00 pm

Moderator: **Barbara D. Broome,** U.S. Army Research Lab. (USA)

Speed Networking Social

5:00 to 6:30 pm

Open to All Attendees

Join us for the next generation of networking. Add a new contact to your network every three minutes while enjoying appetizers at the Pratt Street Ale House. Bring plenty of business cards, practice your pitch, and expand your network.

Interactive Evening Poster Session

6:00 to 7:30 pm

Location: Conv. Ctr. Mezzanine

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Wednesday 22 April.

Concepts for Accelerating Innovation: Redefining the Research Eco-System

3:30 to 5:00 pm

Pellegrino

Russell

This panel discussion will outline and explore novel methods through which research and development collaborations are being arranged to better address the increasing pace of technological change, the globalization of technology, and the need to re-energize University/Industry/Government laboratory synergies.

Moderator: **Dr. John Pellegrino,** Director, Computational and Information Sciences Directorate, US Army Research Laboratory (ARL).

Panel participants from Industry, Government and Academia will include, among others:

Dr. Thomas Russell, Director, ARL, who will describe ARL's newly established Open Campus initiative.

Dr. Nicholas Colaneri, Director, Arizona State University Flexible Electronics & Display Center, who will discuss the Center's progressive Industry Partnership initiatives.

Hyperspectral Imaging Standards Workshop

4:30 to 6:00 pm

Workshop Chair: **David Allen,** National Institute of Standards and Technology (USA)

PURPOSE: Hyperspectral imaging as a field is in the process of maturing from a specialized tool to a routine method applied to many facets of society. Standards provide common reference points that foster an understanding between different entities. This meeting is intended to survey the range of standards currently available and to identify gaps where new standards are needed. The range of standards open for discussion encompass all aspects related to hyperspectral imaging and may include performance specifications, calibration standards, data formats, terminology, and best practices. This workshop will provide an open forum for metrology laboratories, instrument vendors, data product analysts, data product vendors, and end-users. The outcome of this meeting will provide guidance for future activities including an expanded workshop to address areas determined to be significant bottlenecks restricting the full potential of this field. This meeting is open to all DSS registered attendees.

GOALS:
- Provide a forum for the hyperspectral imaging community to discuss current and needed standards
- Identifying international standards organizations that are the most logical homes for new standards
- Address the need for standards to address regulatory requirements
- Discuss the possibility of a uniform set of performance metrics Discuss the need for traceability to national standards
- Consider formalizing best practices.

Thursday 23 April.

Interactive Evening Poster Session

6:00 to 7:30 pm

Open to All symposium attendees

You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

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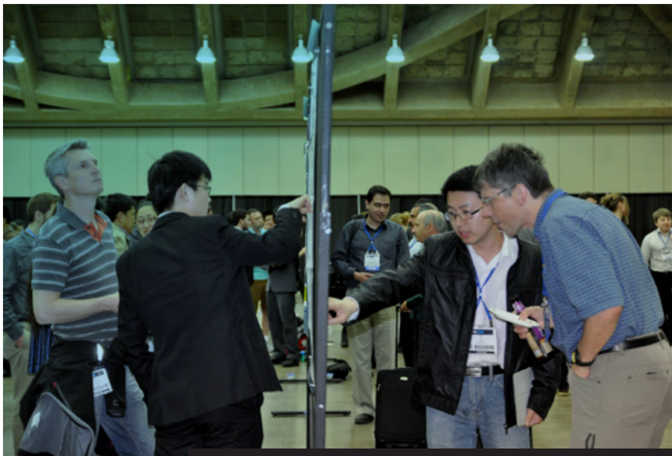


INDUSTRY EVENTS

Explore the business side of DSS 2015. These important events and sessions will provide valuable information and networking opportunities needed to succeed in business. See the event website for full session descriptions and schedule.

FREE - Open to all conference attendees, exhibitors, and exhibition visitors.

PANELS

Interactive discussions on some of the biggest challenges and most promising areas of our industry.

- Sensing, Imaging, and Vision in the Pharmaceutical Industry
- The Future of Sensing — An Industry Perspective
- Getting Hired in 2015 and Beyond

SPECIAL EVENTS

Important networking events for the business community.

- The Infrared Applications: ThermoSense Vendor Session
- Keynote Presentation: National Network for Manufacturing Innovation (NNMI) Update
- Keynote Presentation: Funding Update
- Roundtable Discussion: US Munitions List Category XII Proposed Rule Changes
- ITAR and Other International Trade Regulations
- Doing Business Globally: Legal Best Practices for Ensured Success
- Charting a Course in the Photonics Industry
- DARPA Research Interests in Microelectronics

WORKSHOPS

Learn essential skills for business.

- Early Stage Technology Commercialization by MIRTHE, Princeton Univ.
- TEDCO Workshop on Commercialization

JOB FAIR

Meet recruiters on the exhibit floor.

Job Fair 21 to 22 April

WORLD-CLASS EXHIBITION

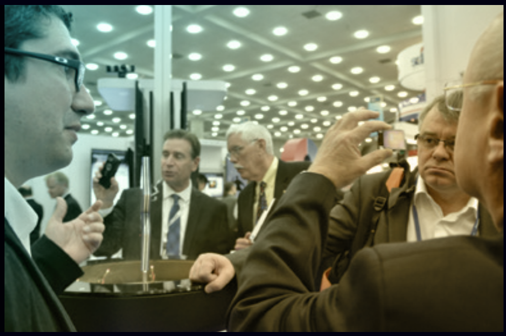
Meet the best suppliers face-to-face.

- **DSS EXPO** 21 to 23 April

SEE WEB FOR UPDATES
www.spie.org/dss15program

E

EXHIBITION



The East Coast's largest optics and photonics exhibition

DSS EXPO

Save time and money by meeting with 450 suppliers from both symposia. Gather with a high concentration of companies sharing their newest products, latest innovations, and cutting-edge technologies. Also see the job fair, interactive technology displays, and more.

Featured Technologies:

- Cameras and CCD Components
- Chemical and Biological Analysis
- Defense, Security, Law Enforcement
- Detectors, Sensors
- Electronic Components and Digital Imaging
- Fiber Optic Components, Equipment, and Systems
- High-Speed Imaging and Sensing
- Industrial Sensing and Measurement
- Infrared Detectors and Systems
- Lasers and Other Light Sources, Laser Accessories, and Laser Systems
- LED, OLED, Non-laser Light Sources
- Machine Vision, Factory Automation
- Optical Coatings, Thin Films
- Optical Components – Lenses, Filters, Mirrors, Other
- Optical Design and Engineering
- Optics Manufacturing
- Robotics and Unmanned Systems
- Spectroscopy Devices and Equipment
- Structural and Infrastructure Sensing
- Test and Measurements, Metrology
- Vehicle Sensing and Control
- Emerging Photonics Technologies

EXHIBITION DATES AND HOURS

Tuesday 21 April · 10:00 am to 5:00 pm

Wednesday 22 April · 10:00 am to 5:00 pm

Thursday 23 April · 10:00 am to 2:00 pm

Don't miss additional opportunities to engage and network

NEW TECHNOLOGY DEMOS AND DISPLAYS

See innovations from our exhibitors in this special showcase. Get an up-close look at the latest in technologies—examples from last year include smartphone thermal imaging, high-dexterity manipulation systems, and 6 axis motion systems.

"SPIE has had a particular focus at times on applications and uses of photonics that I think has spurred a lot of great thought on how problems can be solved using photonics. Not just advancing the state of the art, but actually looking at the applications has been a great contribution that SPIE has made."

David Honey
Office of the Director of National Intelligence

2015 SENSING TECHNOLOGY+ APPLICATIONS.

COMMERCIAL, INDUSTRIAL, AND CONSUMER SENSORS

CO-LOCATED WITH

SPIE DEFENSE + SECURITY

SYMPOSIUM CHAIR

Wolfgang Schade
Clausthal Univ. of Technology and Fraunhofer Heinrich-Hertz Institute (Germany)

SYMPOSIUM CO-CHAIR

Ming C. Wu
Electrical Engineering & Computer Sciences, University of California, Berkeley (USA)

STEERING COMMITTEE

Barbara D. Broome
U.S. Army Research Lab. (USA)

Michael T. Eismann
Air Force Research Lab. (USA)

Kevin G. Harding
GE Global Research (USA)

Kenneth R. Israel
Lockheed Martin Corp. (USA)

Robert Lieberman
Lumoptix, LLC (USA)

David A. Whelan
Boeing Defense, Space, and Security (USA)

TECHNICAL CONFERENCE CHAIRS

Sos S. Agaian, The Univ. of Texas at San Antonio (USA)

Fauzia Ahmad, Villanova Univ. (USA)

Mehdi F. Anwar, Univ. of Connecticut (USA)

Christopher S. Baldwin, Weatherford International Ltd. (USA)

Jerry J. Benterou, Lawrence Livermore National Lab. (USA)

Misty Blowers, Air Force Research Lab. (USA)

Jerome J. Braun, (USA)

Barbara D. Broome, U.S. Army Research Lab. (USA)

Joe C. Campbell, Univ. of Virginia (USA)

Chein-I Chang, Univ. of Maryland, Baltimore County (USA)

Kuanglin Chao, USDA Agricultural Research Service (USA)

Brian A. Chin, Auburn Univ. (USA)

Richard A. Crocombe, Thermo Fisher Scientific Inc. (USA)

Thomas W. Crowe, Virginia Diodes, Inc. (USA)

Brian M. Cullum, Univ. of Maryland, Baltimore County (USA)

Liyi Dai, U.S. Army Research Office (USA)

Sachin Dekate, GE Global Research (USA)

Nibir K. Dhar, U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Eric Donkor, Univ. of Connecticut (USA)

Mark A. Druy, (USA)

Eliza Yingzi Du, Qualcomm Inc. (USA)

Henry H. Du, Stevens Institute of Technology (USA)

Qian Du, Mississippi State Univ. (USA)

Achyut K. Dutta, Banpil Photonics, Inc. (USA)

Michael R. Frey, Bucknell Univ. (USA)

Claudia Gärtner, microfluidic ChipShop GmbH (Germany)

Günter G. Gauglitz, Eberhard Karls Univ. Tübingen (Germany)

David L. Hall, The Pennsylvania State Univ. (USA)

Timothy P. Hanratty, U.S. Army Research Lab. (USA)

Kevin G. Harding, GE Global Research (USA)

Michael J. Hayduck, Air Force Research Lab. (USA)

Sheng-Jen (Tony) Hsieh, Texas A&M Univ. (USA)

Bormin Huang, Univ. of Wisconsin-Madison (USA)

Mark A. Itzler, Princeton Lightwave, Inc. (USA)

Sabah A. Jassim, The Univ. of Buckingham (United Kingdom)

Bahram Javidi, Univ. of Connecticut (USA)

Moon S. Kim, USDA Agricultural Research Service (USA)

Chulhee Lee, Yonsei Univ. (Korea, Republic of)

Yunsong Li, Xidian Univ. (China)

Robert A. Lieberman, Lumoptix LLC (USA)

James Llinas, Univ. at Buffalo (USA)

Samuel J. Lomonaco, Univ. of Maryland, Baltimore County (USA)

Tariq Manzur, Naval Undersea Warfare Ctr. (USA)

Manuel Martinez-Corral, Univ. de València (Spain)

Osamu Matoba, Kobe Univ. (Japan)

Eric S. McLamore, Univ. of Florida (USA)

John M. Myers, Harvard Univ. (USA)

Gary Pickrell, Virginia Polytechnic Institute and State Univ. (USA)

Andrew R. Pirich, ACP Consulting (USA)

Dan O. Popa, Univ. of Texas at Arlington (USA)

Isaac R. Rodriguez-Chavez, National Institute of Dental and Craniofacial Research (USA)

Debbie. G. Senesky, Stanford Univ. (USA)

Jung-Young Son, Konyang Univ. (Korea, Republic of)

Šárka O. Southern, Gaia Medical Institute (USA)

Jonathan Stallings, U.S. Army Ctr. for Environmental Health Research (USA)

Adrian Stern, Ben-Gurion Univ. of the Negev (Israel)

Harold H. Szu, U.S. Army Research Office (USA)

Eric Udd, Columbia Gorge Research (USA)

Tuan Vo-Dinh, Fitzpatrick Institute for Photonics, Duke Univ. (USA)

Anbo Wang, Virginia Polytechnic Institute and State Univ. (USA)

Muthu B.J. Wijesundara, The Univ. of Texas at Arlington Research Institute (USA)

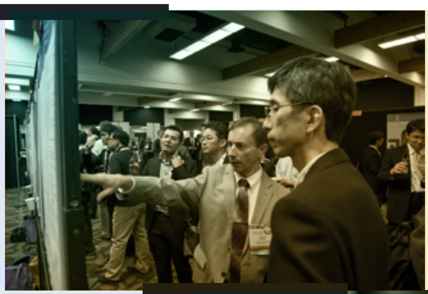
Toru Yoshizawa, NPO 3D Associates Japan

Joseph N. Zalameda, NASA Langley Research Ctr. (USA)

Song Zhang, Iowa State Univ. (USA)

Yufeng Zheng, Alcorn State Univ. (USA)

Help expand and develop commercial and industrial sensing technologies



We invite you to participate in SPIE Sensing Technology + Applications, a major symposium focused on commercial and industrial sensing technologies and applications.

The field of sensors, and in particular those with photonics-based capabilities, is rapidly expanding and offers a rich environment for the development and deployment of new technologies. Humans carry multiple sensors with them every day in their phones and portable devices, and sensors and sensor networks are used across the globe in almost every conceivable industry and application. The potential of leveraging real-time data produced from a global network of distributed sensors opens up a world of new opportunities.

SPIE Sensing Technology + Applications brings together the global community to learn about the newest technologies and how these are driving new applications in healthcare, industrial processing, manufacturing, communications, transportation, agriculture, the environment, and more. Participants in Sensing Technology + Applications will benefit from the meeting's co-location with SPIE Defense + Security, which features a rich array of photonics technologies already developed for dual-use applications.

We look forward to meeting with you in Baltimore and developing the next generation of sensing technologies and applications to improve life and benefit humankind.

Wolfgang Schade, *Symposium Chair*
Clausthal Univ. of Technology and Fraunhofer Heinrich-Hertz Institute (Germany)

Ming C. Wu, *Symposium Co-Chair*
Electrical Engineering & Computer Sciences, University of California, Berkeley (USA)

CONTENTS

BEST PAPER AND BEST STUDENT PAPER AWARDS

The list of awards for the Sensing Technology + Applications symposium may be updated as new awards are added.

Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense

(Conference 9483)

The Conference Chairs and Program Committee for the Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense conference would like to recognize pioneers in the field with a Best Paper Award. Two candidates will be selected: one winner for the Best Paper Award ($1,000 USD) and a Runner-up ($500 USD). This award is open to all authors who present in this conference. Please see next page for complete award eligibility requirements.

Thermosense: Thermal Infrared Applications XXXVII

(Conference 9485)

The Conference Chairs and Program Committee of the oldest and largest technical conference focused on thermal infrared applications are pleased to announce the addition of a Best Paper Award and Best Student Paper Award. Winners will be notified by email.

All papers submitted will be considered for the Best Paper Award and one paper will be selected.

Students who wish to be considered for the Best Student Paper Award must submit their paper for consideration. The Award Contact to submit papers for consideration is Dr. Sheng-Jen (Tony) Hsieh at hsieh@tamu.edu.

Please see next page for complete award eligibility requirements.

Smart Biomedical and Physiological Sensor Technology XII

(Conference 9487)

The Conference Chairs and Program Committee for the Smart Biomedical and Physiological Sensor Technology XII conference would like to recognize pioneers in the field with a Best Paper Award. Two candidates will be selected: one winner for the Best Paper Award ($1,000 USD) and a Runner-up ($500 USD). This award is open to all authors who present in this conference. Please see next page for complete award eligibility requirements.

Sensing for Agriculture and Food Quality and Safety VII

(Conference 9488)

The Conference Chairs and Program Committee for the Sensing for Agriculture and Food Quality and Safety VII conference would like to recognize pioneers in the field with a Best Paper Award. Two candidates will be selected: one winner for the Best Paper Award ($1,000 USD) and a Runner-up ($500 USD). This award is open to all authors who present in this conference. Please see next page for complete award eligibility requirements.

Advances in Global Health through Sensing Technologies 2015

(Conference 9490)

The Conference Chairs and Program Committee for the conference would like to recognize pioneers in the field with a Best Paper Award. Two candidates will be selected: one winner for the Best Paper Award ($1,000 USD) and a Runner-up ($500 USD). This award is open to all authors who present in this conference. Please see next page for complete award eligibility requirements.

Advanced Photon Counting Techniques IX

(Conference 9492)

The Conference Chair and Program Committee for the Advanced Photon Counting Techniques IX conference would like to recognize pioneers in the field with a Best Paper Award. Two candidates will be selected: one winner for the Best Paper Award ($1,000 USD) and a Runner-up ($500 USD). This award is open to all authors who present in this conference. Please see next page for complete award eligibility requirements.

Three-Dimensional Imaging, Visualization, and Display 2015

(Conference 9495)

The Fumio Okano Best 3D Paper Prize is sponsored by NHK-ES, and is presented annually in memory of Dr. Fumio Okano for his enduring contributions to the field of 3D TV and Display. Please see the conference website for additional information.

Independent Component Analyses, Compressive Sampling, Large Data Analyses (LDA), Neural Networks, Biosystems, and Nanoengineering XIII

(Conference 9496)

This conference features six awards in human sciences and engineering annually:

- Compressive Sensing
- Large Data Analyses
- ICA
- Nanoengineering
- Wellness Engineering
- System Biology

The nomination and selection procedure for these awards is done by the previous recipients, similar to other notable awards in science. Please see the Awards web page at http://www.ica-wavelet.org for history, a list of past recipients and additional information.

Machine Intelligence and Bio-inspired Computation: Theory and Applications IX

(Conference 9494B)

The Conference Chair and Program Committee for the Machine Intelligence and Bio-inspired Computation: Theory and Applications conference would like to recognize pioneers in the field with a Best Paper Award. All submitted papers will be considered, provided they meet the award eligibility requirements shown on the next page. Five winners will be selected and notified by email.

Mobile Multimedia/Image Processing, Security, and Applications 2015

(Conference 9497)

The Conference Chairs and Program Committee for the Mobile Multimedia/Image Processing, Security, and Applications conference would like to recognize pioneers in the field with a Best Paper Award. Eight candidates will be selected and notified by email. The candidate papers will be presented in a special session and one of the eight papers will be selected to receive the Best Paper Award. Please see next page for complete award eligibility requirements. Papers must choose "Nominate for Best Paper Award" as one of their topics during abstract submission in order to be considered.

AWARD ELIGIBILITY REQUIREMENTS

(excluding Conf. 9496)

BEST PAPER AWARDS

In order to be considered for a Best Paper Award:

- Presenter must make their oral or poster presentation as scheduled.
- Manuscript must be submitted to the Proceedings of SPIE. The award decision is based on manuscript submission.

Please see the conference award description and conference website to check for possible additional requirements.

BEST STUDENT PAPER AWARDS

In order to be considered for a Best Student Paper Award:

- Student must be the presenting author at the conference and must make their presentation as scheduled.
- Student must be the leading author of the manuscript and the manuscript must be submitted to the Proceedings of SPIE. The award decision is based on manuscript submission.
- Student must send a message to the designated Award Contact to submit their paper for consideration. This should be done after you have submitted your abstract, and must include your paper number and paper title. See the conference award listing for Award Contact information.

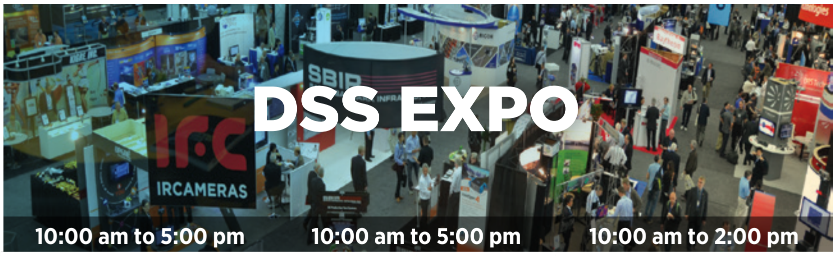
Please see the conference award description and conference website to check for possible additional requirements.

EVALUATION CRITERIA

A panel coordinated by the Conference Chairs will evaluate all papers submitted for consideration of high quality content. Attention may be given to 1) the innovation, clarity, and style of both the presentation at the conference and the manuscript submitted for publication, and 2) the importance of the work to the field.

DAILY CONFERENCE SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
DSS 2015 SYMPOSIUM PLENARY PRESENTATION Monday 20 April 2015 · 5:00 to 6:00 pm **Alan R. Shaffer,** Principal Deputy Assistant Secretary of Defense Research and Engineering, Department of Defense	DSS EXPO 10:00 am to 5:00 pm	10:00 am to 5:00 pm	10:00 am to 2:00 pm	
WELCOME RECEPTION, 6:15 to 7:45 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	**DEDICATED EXHIBITION TIME,** 10:00 am to 1:00 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	



Imaging and Sensing Technologies

9480 **Fiber Optic Sensors and Applications XII** (Pickrell, Udd, Du)

9481 **Image Sensing Technologies: Materials, Devices, Systems, and Applications II** (Dhar, Dutta)

9482 **Next-Generation Spectroscopic Technologies VIII** (Druy, Crocombe)

9483 **Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense** (Anwar, Crowe, Manzur)

9484 **Compressive Sensing IV** (Ahmad)

Sensing for Industry, Environment, and Health

9485 **Thermosense: Thermal Infrared Applications XXXVII** (Hsieh)

9486 **Advanced Environmental, Chemical, and Biological Sensing Technologies XII** (Vo-Dinh, Lieberman, Gauglitz)

9487 **Smart Biomedical and Physiological Sensor Technology XII** (Cullum, McLamore)

9489 **Dimensional Optical Metrology and Inspection for Practical Applications IV** (Harding, Yoshizawa)

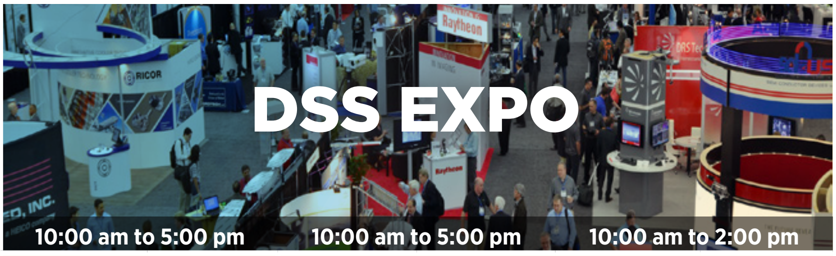
9488 **Sensing for Agriculture and Food Quality and Safety VII** (Kim, Chao, Chin)

9490 **Advances in Global Health through Sensing Technologies 2015** (Southern)

9491 **Sensors for Extreme Harsh Environments II** (Senesky, Dekate)

THIS PROGRAM IS CURRENT AS OF DECEMBER 2014

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
DSS 2015 SYMPOSIUM PLENARY PRESENTATION Monday 20 April 2015 · 5:00 to 6:00 pm **Alan R. Shaffer,** Principal Deputy Assistant Secretary of Defense Research and Engineering, Department of Defense	DSS EXPO 10:00 am to 5:00 pm	DSS EXPO 10:00 am to 5:00 pm	DSS EXPO 10:00 am to 2:00 pm	
WELCOME RECEPTION, 6:15 to 7:45 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	**DEDICATED EXHIBITION TIME,** 10:00 am to 1:00 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	



Emerging Technologies

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
	9493 **Energy Harvesting and Storage: Materials, Devices, and Applications VI** (Dhar, Dutta)	9492 **Advanced Photon Counting Techniques IX** (Itzler)	9492 (continued)	
	9494B **Machine Intelligence and Bio-inspired Computation: Theory and Applications IX** (Blowers)	9494A **Sensors for Next-Generation Robotics II** (Popa, Wijesundara)		

Data Visualization

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
9495 **Three-Dimensional Imaging, Visualization, and Display 2015** (Javidi, Son)	9495 (continued)			

Information Systems and Networks: Processing, Fusion, and Knowledge Generation

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
9497 **Mobile Multimedia/Image Processing, Security, and Applications 2015** (Agaian, Jassim, Du)	9497 (continued)		9496 **Independent Component Analyses, Compressive Sampling, Large Data Analyses (LDA), Neural Networks, Biosystems, and Nanoengineering XIII** (Szu)	9496 (continued)
	9498 **Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2015** (Braun)	9500 **Quantum Information and Computation XIII** (Donkor, Pirich, Hayduk)	9500 (continued)	9500 (continued)
9499 **Next-Generation Analyst III** (Broome, Hanratty, Hall, Llinas)	9499 (continued)		9501 **Satellite Data Compression, Communications, and Processing XI** (Huang, Chang)	9501 (continued)

CONFERENCE 9480

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9480

Fiber Optic Sensors and Applications XII

Conference Chairs: **Gary Pickrell,** Virginia Polytechnic Institute and State Univ. (USA); **Eric Udd,** Columbia Gorge Research (USA); **Henry H. Du,** Stevens Institute of Technology (USA)

Conference Co-Chairs: **Christopher S. Baldwin,** Weatherford International Ltd. (USA); **Jerry J. Benterou,** Lawrence Livermore National Lab. (USA); **Anbo Wang,** Virginia Polytechnic Institute and State Univ. (USA)

Program Committee: **Ole Bang,** Technical Univ. of Denmark (Denmark); **Eric A. Bergles,** BaySpec Inc. (USA); **Jeff Bush,** Optiphase, Inc. (USA); **Kevin Peng Chen,** Univ. of Pittsburgh (USA); **Brian Culshaw,** Univ. of Strathclyde (United Kingdom); **Abdessama Elyamani,** Northrop Grumman Navigation Systems (USA); **Xudong Fan,** Univ. of Michigan (USA); **Yoel Fink,** Massachusetts Institute of Technology (USA); **Eric Lee Goldner,** US Sensor Systems, Inc. (USA); **Tom W. Graver,** Micron Optics, Inc. (USA); **Ming Han,** Univ. of Nebraska-Lincoln (USA); **Hajime Haneda,** National Institute for Materials Science (Japan); **Daniel Homa,** Virginia Polytechnic Institute and State Univ. (USA); **Kazuo Hotate,** The Univ. of Tokyo (Japan); **Jiri Kanka,** Institute of Photonics and Electronics of the ASCR, v.v.i. (Czech Republic); **Gurbinder Kaur,** Thapar Univ. (India); **Victor I. Kopp,** Chiral Photonics, Inc. (USA); **Katerina Krebber,** Bundesanstalt für Materialforschung und -prüfung (Germany); **Steven T. Kreger,** Luna Innovations Inc. (USA); **David A. Krohn,** Light Wave Venture Consulting, LLC (USA); **Paul Lefebvre,** LxDATA (Canada); **Alexis Mendez,** MCH Engineering LLC (USA); **Stephen J. Mihailov,** National Research Council Canada (Canada); **Thomas D. Monte,** KVH Industries, Inc. (USA); **Glen A. Sanders,** Honeywell Technology (USA); **Fei Tian,** Stevens Institute of Technology (USA); **Jasbinder S. Sanghera,** U.S. Naval Research Lab. (USA); **Dennis J. Trevor,** OFS Labs. (USA); **Xingwei Wang,** Univ. of Massachusetts Lowell (USA); **Reinhardt Willsch,** Institut für Photonische Technologien e.V. (Germany); **Hai Xiao,** Clemson Univ. (USA); **Yizheng Zhu,** Virginia Polytechnic Institute and State Univ. (USA)

WEDNESDAY 22 APRIL

SESSION 1. . . . . WED 8:00 AM TO 10:00 AM

Bragg Grating I

Session Chair: **Gary Pickrell,**
Virginia Polytechnic Institute and State Univ. (USA)

Fiber optic sensors for structural monitoring: a 30 year perspective *(Invited Paper)*, Eric Udd, Columbia Gorge Research LLC (USA) . . . . [9480-1]

Fiber optic sensing goes mainstream *(Invited Paper)*, Tom W. Graver, Micron Optics, Inc. (USA) . . . . [9480-2]

Insight into fiber Bragg pressure sensor response at 100 MHz interrogation rates under various dynamic loading conditions *(Invited Paper)*, George Rodriguez, Los Alamos National Lab. (USA) . . . . [9480-3]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 2 . . . . WED 1:00 PM TO 2:00 PM

Bragg Grating II

Session Chair: **Gary Pickrell,**
Virginia Polytechnic Institute and State Univ. (USA)

Distributed Rayleigh scatter dynamic strain sensing above the scan rate with optical frequency domain reflectometry, Stephen T. Kreger, Justin Klein, Joseph J. Bos, Nur Aida Abdul Rahim, Luna Innovations Inc. (USA) . . . . [9480-4]

Interrogating adhesion using fiber Bragg grating sensing technology, Roger D. Rasberry, Garth D. Rohr, William K. Miller, Sandia National Labs. (USA); Eric Udd, Columbia Gorge Research LLC (USA); Noah T. Blach, U.S. Air Force Academy (USA); Ryan A. Davis, David Calkins, R. Allen Roach, David S. Walsh, James R. McElhanon, Sandia National Labs. (USA). . . . . [9480-5]

Residual internal stress optimization for EPON 828/DEA thermoset resin using fiber Bragg grating sensors, Garth D. Rohr, Amy L. Kaczmarowski, Mark Stavig, Cory Gibson, Sandia National Labs. (USA); Eric Udd, Columbia Gorge Research LLC (USA); R. Allen Roach, Rex Jaramillo, Roger D. Rasberry, Sandia National Labs. (USA) . . . . [9480-6]

SESSION 3 . . . . WED 2:00 PM TO 3:00 PM

Bragg Grating III

Session Chair: **Eric Udd,** Columbia Gorge Research LLC (USA)

Influence of dynamic thermal effects on durability of optical fiber in the fiber-optic temperature sensor, Alexandre V. Polyakov, Belarusian State Univ. (Belarus). . . . . [9480-7]

Fiber optic anemometer based on silicon Fabry-Perot interferometer, Ming Han, Guigen Liu, Univ. of Nebraska-Lincoln (USA); Weilin W. Hou, U.S. Naval Research Lab. (USA) . . . . [9480-8]

High-resolution wavelength shift detection of optical signals with low-cost, compact readouts, Peter Kiesel, Alex Hegyi, Ajay Raghavan, Alexander Lochbaum, Julian Schwartz, Bhaskar Saha, Anurag Ganguli, Kyle Arakaki, PARC, a Xerox Co. (USA) . . . . [9480-9]

SESSION 4 . . . . WED 3:30 PM TO 5:50 PM

Oil and Gas Applications

Session Chair: **Henry H. Du,** Stevens Institute of Technology (USA)

Novel sensing materials for harsh environment subsurface chemical sensing applications *(Invited Paper),* Paul R. Ohodnicki, Thomas Brown, Congjun Wang, Xin Su, National Energy Technology Lab. (USA) . . . . . . [9480-42]

Applications for fiber optic sensing in the upstream oil and gas industry, Christopher S. Baldwin, Weatherford International Ltd. (USA) . . . . [9480-10]

Operational verification of a blow out preventer (BOP) utilizing fiber Bragg grating based strain gauges, Alan Turner, Dan Thibodeau, Philippe Loustau, Lloyd's Register Energy-Drilling (USA) . . . . [9480-11]

Optical fiber sensor based on Mach-Zehnder interferometer for monitoring CO2 in carbon sequestration application, Luis B. Melo, Geoff Burton, Peter Wild, Univ. of Victoria (Canada). . . . . [9480-12]

Adapting long gauge vibrofibre to measure fracking activities down well for successful oil and gas exploration and production, Peter Kung, QPS Photronics Inc. (Canada); Maria I. Comanici, McGill Univ. (Canada) . . . [9480-13]

Sub-Hz C-band diode laser for oil exploration, Wei Liang, Vladimir S. Ilchenko, Elijah B. Dale, Danny Eliyahu, Anatoliy A. Savchenkov, Andrey B. Matsko, David J. Seidel, Lute Maleki, OEwaves, Inc. (USA). . . . . [9480-14]

THIS PROGRAM IS CURRENT AS OF DECEMBER 2014

THURSDAY 23 APRIL

SESSION 5 . . . . THU 8:00 AM TO 10:00 AM

Specialty Fiber Sensors I

Session Chair: **Ming Han,** Univ. of Nebraska-Lincoln (USA)

Specialty fiber optic applications for harsh and high radiation environments *(Invited Paper)*, Brian G. Risch, Prysmian Group (USA) . . . . [9480-15]

A polarization maintaining fiber optimized for high temperature gyroscopes, Andy M. Gillooly, Judith Hankey, Frank Tutu, Fibercore Ltd. (United Kingdom). . . . . [9480-16]

Compression of quantum data using compressed sensing, Marcin Kowalski, Marek Zyczkowski, M. Karol, Military Univ. of Technology (Poland) . . . [9480-17]

A miniature turn-around for distributed temperature sensing, Xiaoguang Sun, David T. Burgess, Kyle Bedard, Jie Li, Mike Hines, OFS (USA) . . . [9480-18]

Biomimetic optical sensor for aerospace applications, Susan A. Frost, NASA Ames Research Ctr. (USA); Cameron H. G. Wright, Steven F. Barrett, Univ. of Wyoming (USA) . . . . [9480-19]

SESSION 6 . . . . THU 10:30 AM TO 11:50 AM

Specialty Fibers II

Session Chair: **Tom W. Graver,** Micron Optics, Inc. (USA)

Multicore fiber strain sensor with increased sensitivity, Amy Van Newkirk, Jose E. Antonio-López, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Guillermo Salceda-Delgado, Ctr. de Investigaciones en Óptica, A.C. (Mexico); Mohammad Umar Piracha, FAZ Technology Research Inc. (USA); Rodrigo Amezcua-Correa, Axel Schülzgen, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA). . . . . [9480-20]

Few-mode fiber based sensor in biomedical application, Jing Zhang, A*STAR National Metrology Ctr. (Singapore) . . . . [9480-21]

Applying a correlation algorithm to a microring resonator based wavelength shift demodulator, German Vargas, Escuela Superior Politécnica del Litoral (Ecuador) . . . . [9480-22]

Nanostructured sapphire fiber for high temperature chemical sensing, Hui Chen, Fei Tian, Stevens Institute of Technology (USA); Jiri Kanka, Institute of Photonics and Electronics of the ASCR, v.v.i. (Czech Republic); Henry H. Du, Stevens Institute of Technology (USA) . . . . [9480-23]

Lunch Break and Exhibition Time . . . . Thu 11:50 am to 1:20 pm

SESSION 7 . . . . THU 1:20 PM TO 2:40 PM

Special Topics I

Session Chair: **Fei Tian,** Stevens Institute of Technology (USA)

In-line fiber optic sensors for absolute measurement of high temperature using gas as sensing element *(Invited Paper)*, Ming Han, Univ. of Nebraska-Lincoln (USA). . . . . [9480-24]

Optimization of detonation velocity measurements using a chirped fiber Bragg grating, Yohan Barbarin, Alexandre S. Lefrançois, Jérôme Luc, Guillaume Zaniolo, Vincent Chuzeville, Laurent Jacquet, CEA Gramat (France); Sylvain Magne, CEA LIST (France); Antoine Osmont, CEA Gramat (France) . . . . [9480-25]

High electric field measurement using slab coupled optical sensors, Nikola Stan, Richard H. Selfridge, Stephen M. Schultz, Brigham Young Univ. (USA) . . . . [9480-26]

Development of the wide field and high density type of bundle fiber for in vivo micro-imaging of bioluminescence, Yoriko Ando, Takashi Sakurai, Kowa Koida, Toyohashi Univ. of Technology (Japan); Mitsuo Natsume, Denkosha Co., Ltd. (Japan); Rika Numano, Toyohashi Univ. of Technology (Japan) . . . [9480-27]

SESSION 8 . . . . THU 2:40 PM TO 5:20 PM

Special Topics II

Session Chair: **George Rodriguez,** Los Alamos National Lab. (USA)

Measurements of UV-A radiation and hazard limits from some types of outdoor lamps, Essam Elmoghazy, National Institute For Standards (Egypt) . . . . [9480-28]

Real-time distributed DAS and DTS optical sensing advantages and data compression techniques for the application of hydraulic fracture monitoring, Peter Hayward, Deep Desai, Ifie Nyerhovwo, Fotech Solutions Ltd. (United Kingdom). . . . . [9480-29]

Near-infrared absorption fiber optic sensors for ultra-sensitive CO_2 detection, Xinyuan Chong, Ki-Joong Kim, Oregon State Univ. (USA); Paul R. Ohodnicki, National Energy Technology Lab. (USA); Chih-Hung Chang, Alan X. Wang, Oregon State Univ. (USA) . . . . [9480-30]

A fiber-optic current sensor for lightning measurement applications, Truong X. Nguyen, Jay J. Ely, George N. Szatkowski, NASA Langley Research Ctr. (USA). . . . . [9480-31]

High frequency strain measurements with fiber Bragg grating sensors, Jan Koch, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) and Clausthal Univ. of Technology (Germany); Martin Angelmahr, Wolfgang Schade, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) . . . . [9480-32]

Fiber-optical sensors for enhanced battery safety, Jan Meyer, Antonio Nedjalkov, Technische Univ. Clausthal (Germany); Alexander Doering, Martin Angelmahr, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany); Wolfgang Schade, Technische Univ. Clausthal (Germany) and Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) . . . . [9480-33]

New design for a wavelength demultiplexing device, Konrad Bethmann, Elke Pichler, Technische Univ. Clausthal (Germany); Urs Zywietz, Laser Zentrum Hannover e.V. (Germany); Thomas Schimdt, Uwe Gleissner, Univ. of Freiburg (Germany); Ulrike Willer, Technische Univ. Clausthal (Germany); Wolfgang Schade, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) and Technische Univ. Clausthal (Germany). . . . . [9480-34]

Femtosecond laser processing of evanescence field coupled waveguides in single mode glass fibers for optical 3D shape sensing and navigation, Christian Waltermann, Anna Lena Baumann, Martin Angelmahr, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany); Wolfgang Schade, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) and Technische Univ. Clausthal (Germany). . . . . [9480-35]

CONFERENCE 9481

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9481

Image Sensing Technologies: Materials, Devices, Systems, and Applications II

Conference Chairs: **Nibir K. Dhar,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Achyut K. Dutta,** Banpil Photonics, Inc. (USA)

Program Committee: **Homayoon Ansari,** Jet Propulsion Lab. (USA); **Arvind I. D'Souza,** DRS Sensors & Targeting Systems, Inc. (USA); **Ravi Dutt,** Booz Allen Hamilton Inc. (USA); **Michael D. Gerhold,** U.S. Army Research Office (USA); **John E. Hubbs,** Ball Aerospace & Technologies Corp. (USA); **Nobuhiko P. Kobayashi,** Univ. of California, Santa Cruz (USA); **Sanjay Krishna,** The Univ. of New Mexico (USA); **Robert Olah,** Banpil Photonics, Inc. (USA); **Adam Piotrowski,** VIGO Systems S.A. (Poland); **Siva Sivananthan,** EPIR Technologies, Inc. (USA); **Krishna Swaminathan,** Intel Corp. (USA); **Rama Venkatasubramanian,** RTI International (USA); **Priyalal S. Wijewarnasuriya,** U.S. Army Research Lab. (USA)

WEDNESDAY 22 APRIL

OPENING REMARKS . . . . 1:00 PM TO 1:05 PM

Conference Chair: **Nibir K. Dhar,**
U.S. Army Night Vision & Electronic Sensors Directorate (USA)

SESSION 1. . . . . WED 1:05 PM TO 2:45 PM

Advanced Focal Plane Array Technologies

Session Chairs: **Nibir K. Dhar,**
U.S. Army Night Vision & Electronic Sensors Directorate (USA);
Achyut K. Dutta, Banpil Photonics, Inc. (USA)

Integration of optical functionality for image sensing through sub-wavelength geometry design *(Invited Paper)*, Peter B. Catrysse, Stanford Univ. (USA) . . . . [9481-1]

Interaction of two nano particle plasmons for sensor application, Naresh C. Das, U.S. Army Research Lab. (USA) . . . . [9481-2]

CMOS compatible silicon photonics for mid-IR optical sensing, Pao T. Lin, Massachusetts Institute of Technology (USA) . . . . [9481-3]

Development of high performance SWIR InGaAs focal plane array, Richie S. Nagi, Jeremy Bregman, Genki Mizuno, Robert Olah, Achyut K. Dutta, Banpil Photonics, Inc. (USA); Nibir K. Dhar, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9481-4]

Functionalized fluorescent silver nanoparticle surfaces for novel sensing and imaging techniques, Kyle M. Culhane, Kathrin Spendier, Anatoliy O. Pinchuk, Univ. of Colorado at Colorado Springs (USA) . . . . [9481-5]

SWIR photodetector development at Fraunhofer IAF, Frank Rutz, Philipp Kleinow, Rolf Aidam, Matthias Wauro, Lutz Kirste, Wolfgang Bronner, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany); Alexander Sieck, AIM INFRAROT-MODULE GmbH (Germany); Martin Walther, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany). . . . . [9481-6]

SESSION 2 . . . . WED 3:20 PM TO 4:45 PM

Novel Technologies for Imaging

Session Chairs: **Achyut K. Dutta,** Banpil Photonics, Inc. (USA);
Nibir K. Dhar, U.S. Army Night Vision &
Electronic Sensors Directorate (USA)

UV/VIS/NIR imaging technologies: challenges and opportunities *(Invited Paper)*, Rihito Kuroda, Shigetoshi Sugawa, Tohoku Univ. (Japan) . . . . . . [9481-7]

InAs1-xSbx nanopillar photodetectors on GaAs (111)b substrates, Chung Hong Hung, Nanopixel Technologies, LLC (USA); Pradeep N. Senanayake, Univ. of California, Los Angeles (USA); Wook-Jae Lee, Univ. of California, Davis (USA); Alan Farrell, Univ. of California, Los Angeles (USA); Baolai L. Liang, Integrated NanoMaterials Core Lab. (USA); Diana L. Huffaker, Univ. of California, Los Angeles (USA) . . . . [9481-8]

Improved optical resonance in mid-infrared GaAs-based modulating retro-reflectors, Gregory E Triplett, Stanley Ikpe, Univ of Missouri-Columbia (USA) . . . . [9481-9]

Germanium/zinc sulfite distributed Bragg reflectors for large size MOEMS Fabry-Perot interferometers, Julian L. Chee, EPIR Technologies, Inc. (USA); Neelam Gupta, U.S. Army Research Lab. (USA); Silviu Velicu, EPIR Technologies, Inc. (USA) . . . . [9481-10]

High NA, VIS+IR, and athermal low-light camera objective, Markus Lipp, Frank Saupe, Matthias Falk, Martin Forrer, FISBA OPTIK AG (Switzerland) . . . . [9481-11]

THURSDAY 23 APRIL

SESSION 3 . . . . THU 9:00 AM TO 10:00 AM

Imaging Systems and Applications

Session Chairs: **Nibir K. Dhar,**
U.S. Army Night Vision & Electronic Sensors Directorate (USA);
Achyut K. Dutta, Banpil Photonics, Inc. (USA)

Image sensor conversion gain determination in data constrained environment: blending temporal and spatial information for a mean-variance measurement, Blake C. Jacquot, Sean Maguire, Brett Bolla, The Aerospace Corp. (USA) . . . . [9481-12]

Advanced computational sensors technology, Charbel G. Rizk, Johns Hopkins Univ. Applied Physics Lab., LLC (USA). . . . . [9481-13]

360-degree scanning light scattering profiler (SLSP) to quantitatively characterize the front and back light scattering from intraocular lenses (IOLs), Bennett N. Walker, Robert H. James, Don Calogero M.D., Ilko K. Ilev, U.S. Food and Drug Administration (USA) . . . . [9481-14]

The application of machine learning in multi sensor image fusion for activity recognition of mobile device space, Asmaa H. Marhoubi, Eran A. Edirisinghe, Loughborough Univ. (United Kingdom) . . . . [9481-15]

SESSION 4 . . . . THU 10:40 AM TO 11:50 AM

Imaging Applications

Session Chair: **Achyut K. Dutta,** Banpil Photonics, Inc. (USA)

Uncooled LWIR imaging: applications and market analysis *(Invited Paper)*, Satomi Takasawa, Techno Systems Research Co., Ltd. (Japan) . . . . . . [9481-16]

Advanced illumination control algorithm in VHDL, Ricardo M. Sousa, AWAIBA Lda. (Portugal) and Univ. da Madeira (Portugal); Martin Wäny, Pedro Santos, AWAIBA Lda. (Portugal); Morgado Dias, Univ. da Madeira (Portugal) and Madeira Interactive Technologies Institute (Portugal) . . . . [9481-17]

How thermographic mapping can help with enhanced oil recovery, Eric Olsen, Aerial Thermal Imaging (USA) . . . . [9481-18]

Information content capabilities of very high resolution optical space imagery for updating GIS database, Mehmet Alkan, Yildiz Technical Univ. (Turkey); Gurcan Buyuksalih, Bimtas (Turkey); Karsten Jacobsen, Leibniz Univ. Hannover (Germany). . . . . [9481-19]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Aliasing removing of hyperspectral image based on fractal structure matching, Ran Wei, Ye Zhang, Junping Zhang, Harbin Institute of Technology (China) . . . . [9481-20]

A low noise low power 512x256 ROIC for extended wavelength InGaAs FPA, SongLei Huang, Shanghai Institute of Technical Physics (China) . [9481-21]

A telephoto camera system with shooting direction control by gaze detection, Daiki Teraya, Nagaoka Univ. of Technology (Japan) . . . . . . [9481-22]

Reconstruction the system PSF by using the sub pixel technique, Xiaofeng Su, Fansheng Chen, Shanghai Institute of Technical Physics (China) . . [9481-23]

A bionic multi-band polarimetric imaging system, Yong Liu, Jingxiang Yang, Yongqiang Zhao, Northwestern Polytechnical Univ. (China) . . . . [9481-24]

2D imaging of metallic samples by means of resonance frequency measurements, Roberta Guilizzoni, Univ. College London (United Kingdom) . . . . [9481-25]

Enhancing the quality of experience of a portable device by creating an illumination model based on the ambient light sensor readings, Asmaa H. Marhoubi, Helmut E. Bez, Eran A. Edirisinghe, Sara Saravi, Loughborough Univ. (United Kingdom) . . . . [9481-26]

Surface-enhanced Raman scattering on a chemically etched ZnSe surface, Syed K Islam, John Lombardi, Maria Tamargo, City College, City Univ. of New York (USA); Richard Moug, City College, City University of New York (CUNY) (USA) . . . . [9481-27]

Effect of high proton implantation on the device characteristics of InAlGaAs-capped InGaAs/GaAs quantum dot based infrared photodetectors, Sourabh Upadhyay, Arjun Mandal, Hemant J. Ghadi, Dinesh Pal, Indian Institute of Technology Bombay (India); Nagaraju B. V. Subrahmanyam, Pitamber Singh, Bhabha Atomic Research Ctr. (India); Subhananda Chakrabarti, Indian Institute of Technology Bombay (India) . . . . [9481-28]

A detail investigation on quaternary and ternary capped strain coupled quantum dots based infrared photodetectors and effect of rapid thermal annealing temperature, Subhananda Chakrabarti, Hemant J. Ghadi, Sourav Adhikary, Saikalash Shetty, Akshay Balgarkashi, Indian Institute of Technology Bombay (India) . . . . [9481-29]

Studies on abrupt and gradual heterostructured hole barriers in barrier enhanced InAs/GaSb superlattice long wavelength photodetectors, Yi Zhou, Jianxin Chen, Fangfang Wang, Zhicheng Xu, Li He, Shanghai Institute of Technical Physics (China) . . . . [9481-30]

Automated optical system alignment and low order wavefront sensing, Joyce Fang, Cornell Univ. (USA) . . . . [9481-31]

Fluorescence of quantum dots on e-beam patterned and DNA origami substrates, Timothy C. Corrigan, Matthew Kessinger, Ina Nikolli, Concord Univ. (USA); Michael L. Norton, David Neff, Marshall Univ. (USA) . . . . [9481-32]

Analysis for simplified optics coma effection on spectral image inversion of coded aperture spectral imager, Yangyang Liu, Qunbo Lv, Linlin Pei, Jianwei Wang, Academy of Opto-Electronics (China) . . . . [9481-33]

Random laser action in al nanoparticle/Rh6G-doped silica gel, Chao Yang, Guoying Feng, Hong Zhang, Jiayu Yi, Jiajia Yin, Shouhuan Zhou, Sichuan Univ. (China) . . . . [9481-34]

Maximum allowable low-frequency platform vibrations in high resolution satellite missions: challenges and look-up figures, Javad Haghshenas, Satellite Research Institute (Iran, Islamic Republic of) . . . . [9481-35]

Choosing the right video interface for military vision systems, Edward Goffin, John Phillips, Pleora Technologies Inc. (Canada) . . . . [9481-36]

Nanomolecular gas sensor architectures based on functionalized carbon nanotubes for vapor detection, Deon Hines, The City College of New York (USA) . . . . [9481-37]

CONFERENCE 9482

Monday–Wednesday 20–22 April 2015 • Proceedings of SPIE Vol. 9482

Next-Generation Spectroscopic Technologies VIII

Conference Chairs: **Mark A. Druy,** (USA); **Richard A. Crocombe,** Thermo Fisher Scientific Inc. (USA); **David P. Bannon,** Headwall Photonics Inc. (USA)

Program Committee: **Leigh J. Bromley,** Daylight Solutions (USA); **John M. Dell,** The Univ. of Western Australia (Australia); **Richard D. Driver,** Headwall Photonics Inc. (USA); **Jason M. Eichenholz,** Open Photonics, Inc. (USA); **Michael B. Frish,** Physical Sciences Inc. (USA); **Fredrick G. Haibach,** BaySpec, Inc. (USA); **Willem Hoving,** Avantes B.V. (Netherlands); **Vassili Karanassios,** Univ. of Waterloo (Canada); **Martin Kraft,** Carinthian Tech Research AG (Austria); **Jouko O. Malinen,** VTT Technical Research Ctr. of Finland (Finland); **Curtis A. Marcott,** Light Light Solutions, LLC (USA); **Ellen V. Miseo,** Hamamatsu Corp. (USA); **Jeffry J. Santman,** Corning Advanced Optics (USA); **David W. Schiering,** Smiths Detection (USA); **John Seelenbinder,** Agilent Technologies (USA); **Ulrike Willer,** Technische Univ. Clausthal (Germany)

MONDAY 20 APRIL

SESSION 1. . . . . MON 8:00 AM TO 12:10 PM

Miniature, Portable and Handheld Instruments

Session Chair: **Mark A. Druy,** . (USA)

Development of handheld standoff Raman spectrometer for concealed chemical detection, Vincent Y. Lee, David W. Schiering, Smiths Detection Inc. (USA) . . . . [9482-1]

A perspective on the development of portable and hand-held Fourier transform infrared (FT-IR) spectrometers and their application *(Invited Paper)*, David W. Schiering, Josep Arnó, Smiths Detection Inc. (USA). . . [9482-2]

Chromium speciation using battery-operated microplasmas-on-chips and optical emission spectrometry, Jenisse German, Vassili Karanassios, Univ. of Waterloo (Canada). . . . . [9482-3]

Review and recent progress of handheld spectrometry at Thermo Fisher Scientific *(Invited Paper)*, Peidong Wang, Thermo Fisher Scientific Inc. (USA) . . . . [9482-4]

A new point of care device for the detection of transcutaneous bilirubin index based on a novel optical probe, Hasan B. Celebi, Yunus Karamavus, Yildiz Uludag, TÜBITAK National Research Institute of Electronics and Cryptology (Turkey) . . . . [9482-5]

A full featured handheld LIBS analyzer with early results for defense and security, David R. Day, Don Sackett, Brendan Connors, Morgan Jennings, SciAps, Inc. (USA) . . . . [9482-6]

Security and defense applications with a novel handheld mass spectrometer, Christopher D. Brown, 908 Devices Inc. (USA) . . . . [9482-7]

Towards a chip-scale integrated-optic TDLAS methane sensor, Michael B. Frish, Matthew C. Laderer, Physical Sciences Inc. (USA). . . . . [9482-8]

Interband cascade laser spectroscopic sources with extremely low power budgets, Jerry R. Meyer, Chul Soo Kim, U.S. Naval Research Lab. (USA); Mijin Kim, Sotera Defense Solutions, Inc. (USA); William W. Bewley, Charles D. Merritt, Chadwick L. Canedy, Igor Vurgaftman, U.S. Naval Research Lab. (USA) . . . . [9482-9]

Micro-Raman spectroscopy for meat type detection, Martin De Biasio, Carinthian Tech Research AG (Austria); Dirk Balthasar, TOMRA Sorting GmbH (Germany); Philip Stampfer, Raimund Leitner, Carinthian Tech Research AG (Austria) . . . . [9482-10]

Lunch Break . . . . .Mon 12:10 pm to 1:40 pm

SESSION 2 . . . . .MON 1:40 PM TO 5:00 PM

New Instruments and Techniques

Session Chair: **Jeffry J. Santman,** Corning Advanced Optics (USA)

Characterization of ion-assisted induced absorption in A-Si thin-films used for multivariate optical computing, Aditya B. Nayak, Jimmy Price, Bin Dai, David Perkins, Ding Ding Chen, Christopher M. Jones, Halliburton (USA) . . . . [9482-11]

Photoacoustic sensing with micro-tuning forks *(Invited Paper)*, Ulrike Willer, Michael Köhring, Mario Mordmüller, Technische Univ. Clausthal (Germany); Wolfgang Schade, Fraunhofer-Institut für Nachrichtentechnik Heinrich-Hertz-Institut (Germany) . . . . [9482-12]

Latest developments in DLP based NIR spectrometers enable the next generation of compact, portable systems, Eric Pruett, Pedro Gelabert, Texas Instruments Inc. (USA). . . . . [9482-13]

Quantitative energy dispersive x-ray diffraction for identification of counterfeit medicines: preliminary study, Chiaki Crews, Daniel O'Flynn, Aiden L. Sidebottom, Robert D. Speller, Univ. College London (United Kingdom) . . . . [9482-14]

Long-wave infrared spectroscopy for trace chemical agent detection using hypersorbent materials, Dmitry A. Kozak, R. Andrew McGill, Todd H. Stievater, Viet Nguyen, Robert Furstenberg, Marcel W. Pruessner, U.S. Naval Research Lab. (USA) . . . . [9482-15]

Developing mobile LIBS solutions for real world applications, Qun Li, Katherine A. Bakeev, Jing Li, Sean X. Wang, B&W Tek, Inc. (USA) . . . . [9482-16]

Spectral analysis of rare earth elements, Andrzej W. Miziolek, U.S. Army Research Lab. (USA); Madhavi Z. Martin, Oak Ridge National Lab. (USA); Robert V. Fox, Idaho National Lab. (USA); Frank C. DeLucia Jr., U.S. Army Research Lab. (USA) . . . . [9482-17]

A spectroscopic tool for rapid analysis of wear metals in lubricating oil, Stephen Berkebile, Andrzej W. Miziolek, Frank C. De Lucia Jr., U.S. Army Research Lab. (USA); Mark W. Michie II, David M. Green, U.S. Army Aberdeen Test Ctr. (USA). . . . . [9482-18]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 3 . . . . TUE 8:00 AM TO 12:00 PM

Smartphone Spectroscopy

Session Chair: **Richard A. Crocombe,** Thermo Fisher Scientific Inc. (USA)

Is "good enough" good enough for portable visible and near-visible spectrometry? *(Invited Paper)*, Alexander Scheeline, SpectroClick (USA) . . . . [9482-19]

Demonstration of G-Fresnel cellphone spectrometer, Chenji Zhang, The Pennsylvania State Univ. (USA); Perry S. Edwards, Atoptix, LLC. (USA); Zhiwen Liu, The Pennsylvania State Univ. (USA). . . . . [9482-20]

Smartphone spectroscopy: three unique modalities for point-of-care testing *(Invited Paper)*, Kenneth D. Long, Hojeong Yu, Brian T. Cunningham, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9482-21]

iSPEX: a smartphone spectropolarimeter, Frans Snik, Stephanie Heikamp, Ritse C. Heinsbroek, Felix C. M. Bettonvil, Gerard van Harten, Christoph U. Keller, Leiden Observatory (Netherlands); Jeroen H. H. Rietjens, SRON Netherlands Institute for Space Research (Netherlands); Ramón Navarro, NOVA Optical Infrared Instrumentation Group (Netherlands); Arnoud Apituley, Koninklijk Nederlands Meteorologisch Instituut (Netherlands); Hester Volten, Rijksinstituut voor Volksgezondheid en Milieu (Netherlands); Armand Perduijn, Bright LED Solutions B.V. (Netherlands); Sipke Wadman, Willem Hoving, Avantes B.V. (Netherlands); Norbert Schmidt, DDQ (Netherlands). . . . . [9482-22]

Quantum dots, CMOS sensors and cell phones toward point-of-care-diagnostics *(Invited Paper)*, Eleonora Petryayeva, W. Russ Algar, The Univ. of British Columbia (Canada). . . . . [9482-23]

Mobile phone based mini-spectrometer for rapid screening of skin cancer, Tristan B. Swedish, Mira Moufarrej, Thomas Gurry, Edgar Aranda-Michel, Xu Zhang, Prashant Sharma, Marie Noland, Anshuman J. Das, Ramesh Raskar, Massachusetts Institute of Technology (USA) . . . . [9482-24]

Portable computing for mobile micro-instruments: from hand held devices to smart phones and tablets in spectroscopy, Scott Weagant, Vassili Karanassios, Univ. of Waterloo (Canada) . . . . [9482-25]

Smartphone-embedded chemical luminescence-based biosensors for point-of-need applications, Aldo Roda, Elisa Michelini, Luca Cevenini, Donato Calabria, Maria M. Calabretta, Martina Zangheri, Massimo Di Fusco, Massimo Guardigli, Mara Mirasoli, Patrizia Simoni, Univ. degli Studi di Bologna (Italy) . . . . [9482-26]

Gas detection with microelectromechanical Fabry-Perot interferometer technology in cell phone, Rami Mannila, Risto Hyypiö, Anna Rissanen, VTT Technical Research Ctr. of Finland (Finland). . . . . [9482-27]

Lunch Break and Exhibition Time . . . . Tue 12:00 pm to 1:30 pm

SESSION 5 . . . . TUE 1:30 PM TO 3:10 PM

Novel Infrared and Raman Instruments and Applications

Session Chair: **Leigh J. Bromley,** Daylight Solutions Inc. (USA)

MEMS for imaging spectrometry from the visible to the long wave infrared wavelengths, Dilusha K. K. M. B. D. Silva, Dhirendra K. Tripathi, Haifeng Mao, John Bumgarner, Mariusz Martyniuk, Jarek Antoszewski, John M. Dell, Lorenzo Faraone, The Univ. of Western Australia (Australia) . . . . [9482-28]

Determination of stress in silicon wafers using Raman spectroscopy, Martin De Biasio, Lukas Neumaier, Carinthian Tech Research AG (Austria); Eduard Geier, Michael Rösner, Infineon Technologies Austria AG (Austria); Christina Hirschl, Martin Kraft, Carinthian Tech Research AG (Austria). . . . . [9482-29]

Fuel flexibility via real-time Raman fuel-gas analysis for turbine-system control, Michael P. Buric, Benjamin T. Chorpening, Steven D. Woodruff, David Tucker, National Energy Technology Lab. (USA) . . . . [9482-30]

Ubiquitous transmissive Raman spectroscopy for liquid detection in opaque containers, Vincent Y. Lee, David W. Schiering, Smiths Detection Inc. (USA) . . . . [9482-31]

Modular, reconfigurable matched spectral filter spectrometer, Elizabeth C. Schundler, James R. Engel, OPTRA, Inc. (USA); Thomas C. Gruber Jr., MESH, Inc. (USA); Robert Vaillancourt, Ryan Benedict-Gill, David J. Mansur, John Dixon, Kevin Potter, OPTRA, Inc. (USA) . . . . [9482-32]

SESSION 6 . . . . TUE 3:40 PM TO 6:00 PM

Hyperspectral Imaging I

Session Chair: **Ellen V. Miseo,** Analytical Answers, Inc. (USA)

High spatial resolution LWIR hyperspectral sensor, Carson B. Roberts, Andrew Bodkin, James T. Daly, Bodkin Design & Engineering, LLC (USA) . . . . [9482-33]

Dewar-cooler-integrated MWIR spectrometer for high rates and high-dynamic range measurements, Nicolas Guérineau, Sylvain Rommeluère, Yann Ferrec, Guillaume Druart, ONERA (France); Serge Magli, SOFRADIR (France); Gilles Lasfargues, Commissariat à l'Énergie Atomique (France); Eric D. de Borniol, MINATEC (France) . . . . [9482-34]

Compact, high performance hyperspectral system design and applications, Leah Ziph-Schatzberg, Corning Incorporated (USA) . . . . [9482-35]

Portable, stand-off spectral imaging camera for detection of effluents and residues, Neil Goldstein, Benjamin St. Peter, Jonathan Grot, Michael Kogan, Marsha Fox, Pajo Vujkovic-Cvijin, Ryan Penny, Jason A. Cline, Spectral Sciences, Inc. (USA) . . . . [9482-36]

Detection and direct identification of liquid contaminants at standoff distances with an imaging polarimetric spectrometer, Eugene Tsiang, Jason T. Akagi, Adam Oberbeck, Paul G. Lucey, Edward T. Knobbe, Spectrum Photonics, Inc. (USA) . . . . [9482-37]

Longwave infrared compressive hyperspectral imager, Julia Rentz Dupuis, Bogdan R. Cosofret, Physical Sciences Inc. (USA); Michael J. Kirby, Colorado State Univ. (USA). . . . . [9482-38]

Hyperspectral grating optimization and manufacturing considerations, Lovell E. Comstock, Jeffry J. Santman, Corning Specialty Materials, Inc. (USA) . . . . [9482-39]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Divalent chromium doped ZnSe nanoparticles random laser induced by nanosecond laser pulse, Jiayu Yi, Guoying Feng, Chao Yang, Shouhuan Zhou, Sichuan Univ. (China) . . . . [9482-54]

WEDNESDAY 22 APRIL

SESSION 7 . . . . WED 8:00 AM TO 9:20 AM

Chemometrics and Hyperspectral Imaging

Session Chair: **Ulrike Willer,** Technische Univ. Clausthal (Germany)

Fluorescent marker-based and marker-free discrimination between healthy and cancerous human tissues using hyper-spectral imaging, Thomas Arnold, Martin De Biasio, Raimund Leitner, Carinthian Tech Research AG (Austria) . . . . [9482-40]

Transference of chemometric models to non-identical systems, Kellen J. Sorauf, Regis Univ. (USA); Amy J. R. Bauer, TSI Inc. (USA); Frank C. DeLucia Jr., Andrzej W. Miziolek, U.S. Army Research Lab. (USA) . . . . [9482-41]

Spectral data analysis approaches for improved provenance classification, Andrzej W. Miziolek, U.S. Army Research Lab. (USA); Kellen J. Sorauf, Regis Univ. (USA); Amy J. R. Bauer, TSI Inc. (USA); Fank C. De Lucia Jr., U.S. Army Research Lab. (USA) . . . . [9482-42]

Filter selection criteria for the discrimination of strongly overlapping chemical spectra, Kevin J. Major, Menelaos K. Poutous, Kevin F. Dunnill, The Univ. of North Carolina at Charlotte (USA); Kenneth J. Ewing, Jasbinder S. Sanghera, U.S. Naval Research Lab. (USA); Ishwar D. Aggarwal, The Univ. of North Carolina at Charlotte (USA) . . . . [9482-43]

SESSION 8 . . . . WED 9:20 AM TO 10:20 AM

Hyperspectral Imaging II

Session Chair: **Ulrike Willer,** Technische Univ. Clausthal (Germany)

Compact hyperspectral image sensor based on a novel hyperspectral encoder, Alex Hegyi, Joerg Martini, PARC, a Xerox Co. (USA) . . . . [9482-44]

NASA Goddard's LiDAR, Hyperspectral, and Thermal airborne imager (G-LiHT), Lawrence A. Corp, Bruce D. Cook, Elizabeth M. Middleton, NASA Goddard Space Flight Ctr. (USA) . . . . [9482-45]

Characterization of AOTF based Spectropolarimetric Imagers from 400 to 1700 nm, Neelam Gupta, U.S. Army Research Lab. (USA); John C. Morgan, U.S. Army Engineer Research and Development Ctr. (USA); Dennis Suhre, DRS Scientific Inc. (USA). . . . . [9482-46]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:20 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 9 . . . . .WED 1:00 PM TO 3:20 PM

Hyperspectral Imaging III

Session Chair: **David P. Bannon,** Headwall Photonics Inc. (USA)

Low SWaP multispectral sensors using dichroic filter arrays, Todd Jennings, John D. Dougherty, Pixelteq, Inc. (USA) . . . . [9482-47]

Inverse analysis of triarylamine-dye transmission spectra, Daniel Aiken, Scott A. Ramsey, Troy Mayo, Jim Bellemare, Samuel G. Lambrakos, Joseph E. Peak, U.S. Naval Research Lab. (USA) . . . . [9482-48]

Weighted Chebyshev Distance classification method for

hyperspectral imaging, Suleyman Demirci, Turkish Air Force Academy (Turkey); Iþýn Erer, Istanbul Technical Univ. (Turkey); Okan K. Ersoy, Purdue Univ. (USA) . . . . [9482-49]

Optical system design of a Dyson imaging spectrometer based on Fery prism, Linlin Pei, Academy of Opto-Electronics (China). . . . . [9482-50]

errors in imaging of computational imaging spectrometer caused by sampling, Jianwei Wang, Academy of Opto-Electronics (China). . . . . . [9482-51]

Drill core imaging spectrometer record compiling system, Taixia Wu, Lifu Zhang, Hongming Zhang, Qingxi Tong, Institute of Remote Sensing and Digital Earth (China) . . . . [9482-52]

Turbine jet exhaust as proxy for detection of wake vortices, Taumi Daniels, NASA Langley Research Ctr (USA) . . . . [9482-53]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9483

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9483

Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense

Conference Chairs: **Mehdi F. Anwar,** Univ. of Connecticut (USA); **Thomas W. Crowe,** Virginia Diodes, Inc. (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

Program Committee: **Giles Davies,** Univ. of Leeds (United Kingdom); **Gottfried H. Döhler,** Max Planck Institute for the Science of Light (Germany); **Achyut K. Dutta,** Banpil Photonics, Inc. (USA); **M. Saif Islam,** Univ. of California, Davis (USA); **Hiroshi Ito,** Kitasato Univ. (Japan); **Peter Uhd Jepsen,** Technical Univ. of Denmark (Denmark); **Edmund H. Linfield,** Univ. of Leeds (United Kingdom); **Amir Hamed Majedi,** Univ. of Waterloo (Canada); **Taiichi Otsuji,** Tohoku Univ. (Japan); **Nezih Pala,** Florida International Univ. (USA); **Azizur Rahman,** City Univ. London (United Kingdom); **Victor Ryzhii,** Univ. of Aizu (Japan); **Andre U. Sokolnikov,** Visual Solutions and Applications (USA); **Ashok K. Sood,** Magnolia Optical Technologies, Inc. (USA); **Sigfrid K. Yngvesson,** Univ. of Massachusetts Amherst (USA); **Weili Zhang,** Oklahoma State Univ. (USA)

WEDNESDAY 22 APRIL

SESSION 1. . . . . .WED 8:00 AM TO 10:00 AM

Novel Concepts I

Session Chairs: **Thomas W. Crowe,** Virginia Diodes, Inc. (USA); **B. M. Azizur Rahman,** City Univ. London (United Kingdom)

Terahertz nonreciprocal transmission in asymmetry magneto-metasurface *(Invited Paper)*, Sai Chen, Fei Fan, Bo Liu, Shengjiang Chang, Nankai Univ. (China) . . . . [9483-1]

Enhancement of THz signal intensity by plasmonic monopole nanoantenna *(Invited Paper)*, Ekmel Özbay, Bilkent Univ. (Turkey) . . . . [9483-2]

GaN-based terahertz quantum cascade lasers *(Invited Paper)*, Wataru Terashima, Hideki Hirayama, RIKEN (Japan) . . . . [9483-39]

Study on gas molecule adsorption-desorption dynamics on graphene using terahertz emission spectroscopy *(Invited Paper)*, Iwao Kawayama, Osaka Univ. (Japan); Saikat Talapatra, Southern Illinois University-Carbondale (USA); Robert Vajtai, Rice Univ. (USA); Pulickel Madhavapanicker Ajayan, Rice University (USA); Junichiro Kono, Rice Univ. (USA); Tonouchi Masayoshi, Osaka Univ (Japan). . . . . [9483-4]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 2 . . . . WED 1:00 PM TO 3:00 PM

THz Sources I

Session Chairs: **Mehdi F. Anwar,** Univ. of Connecticut (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

Terahertz metamaterials for modulation and detection *(Invited Paper)*, Sameer Sonkusale, Tufts Univ. (USA); Pramod Singh, Tufts University (USA); Saroj Rout, Tufts Univ (USA); Guoqing Fu, Wangren Xu, Tufts University (USA) . . . . [9483-5]

Terahertz-wave detector modules implementing zero-biased InGaAsp Schottky-barrier diodes *(Invited Paper)*, Hiroshi Ito, Kitasato Univ. (Japan). . . . . [9483-6]

THz-wave parametric amplifier using LiNbO3 crystal *(Invited Paper)*, Kodo Kawase, Nagoya Univ. (Japan) and RIKEN (Japan); Kosuke Murate, Kazuki Imayama, Nagoya Univ. (Japan); Shin'ichiro Hayashi, RIKEN (Japan). . . . . [9483-7]

Terahertz oscillators and receivers using electron devices for high-capacity wireless communication *(Invited Paper)*, Safumi Suzuki, Masahiro Asada, Tokyo Institute of Technology (Japan) . . . . [9483-8]

SESSION 3 . . . . .WED 3:30 PM TO 4:30 PM

Keynote Session

Session Chairs: **Thomas W. Crowe,** Virginia Diodes, Inc. (USA); **Taiichi Otsuji,** Tohoku Univ. (Japan)

Recent advances in room temperature THz emitter based on DFG at CQD/NU *(Invited Paper)*, Manijeh Razeghi, Northwestern Univ. (USA) . . . . [9483-9]

SESSION 4 . . . . .WED 4:30 PM TO 6:10 PM

THz Sources II

Session Chair: **Mehdi F. Anwar,** Univ. of Connecticut (USA)

Compact THz receivers *(Invited Paper)*, Thomas W Crowe, Virginia Diodes, Inc. (USA); Eric W Bryerton, Jeffrey L Hesler, Virginia Diodes Inc (USA) . . . . [9483-10]

Chip scale polarization rotator on SOI for mid-IR: design and analysis *(Invited Paper)*, B. M. A Rahman, City Univ. London (United Kingdom); Ajanta Barh, Ravi K Varshney, Indian Institute of Technology Delhi (India); Bishnu P Pal, Mahindra Ecole Centrale (India) . . . . [9483-3]

Radar system components to detect small and fast objects, Axel Hülsmann, Christian Zech, Mathias Klenner, Axel Tessmann, Arnulf Leuther, Michael Schlechtweg, Oliver Ambacher, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany) . . . . [9483-11]

Optical simulation of terahertz antenna using finite difference time domain method, Chao Zhang, Zoran Ninkov, Gregory J. Fertig, Rochester Institute of Technology (USA); Andrew P. Sacco, J. Daniel Newman, Kenneth D. Fourspring, Exelis Geospatial Systems (USA); Paul P. K. Lee, IEEE (USA); Zeljko Ignjatovic, Judith L. Pipher, Craig W. McMurtry, Jagannath Dayalu, Univ. of Rochester (USA) . . . . [9483-12]

THURSDAY 23 APRIL

SESSION 5 . . . . THU 8:00 AM TO 10:10 AM

Advanced Materials and Devices

Session Chairs: **Taiichi Otsuji,** Tohoku Univ. (Japan); **Weili Zhang,** Oklahoma State Univ. (USA)

Metasurface induced terahertz transparency and absorption *(Invited Paper)*, Weili Zhang, Oklahoma State Univ. (USA). . . . . [9483-13]

Optical parameters of ZnMgO/ZnO core-shell structures in THz regime *(Invited Paper)*, Anas Mazady, Abdiel Rivera, Kiarash Ahi, Mehdi Anwar, Univ. of Connecticut (USA). . . . . [9483-14]

Tuning of terahertz metamaterials' resonances via near field coupling *(Invited Paper)*, Abul K Azad, Ctr. for Integrated Nanotechnologies (USA) . . . . [9483-15]

SENSING TECHNOLOGY + APPLICATIONS

Phase characteristics of subwavelength antenna elements for efficient design of terahertz frequency and millimeter-wavelength metasurfaces, Richard J Williams, Andrew J Gatesman, Univ. of Massachusetts Lowell (USA); William E Nixon, US Army National Ground Intelligence Center (USA). . [9483-16]

Sub-THz materials measurements based on low loss corrugated waveguides *(Invited Paper),* Emile de Rijk, Alessandro Macor, SWISSto12 SA (Switzerland) . . . . [9483-33]

SESSION 6 . . . . THU 10:40 AM TO 12:10 PM

Novel Concepts II

Session Chairs: **Thomas W. Crowe,** Virginia Diodes, Inc. (USA); **B. M. Azizur Rahman,** City Univ. London (United Kingdom)

Extreme THz nonlinearities: high-harmonic generation, dynamical Bloch oscillations and interband Zener tunneling in bulk semiconductors *(Invited Paper)*, Christoph Lange, Olaf Schubert, Matthias Hohenleutner, Fabian Langer, Univ. Regensburg (Germany); Benedikt Urbanek, University of Regensburg (Germany); Ulrich Huttner, Daniel Golde, Philipps-Univ. Marburg (Germany); Torsten Meier, Univ. Paderborn (Germany); Mackillo Kira, Stephan W Koch, Philipps-Univ. Marburg (Germany); Rupert Huber, Univ. Regensburg (Germany) . . . . [9483-17]

A review on THz characterization of electronic components and a comparison of THz imaging characterization with other techniques *(Invited Paper)*, Kiarash Ahi, Univ. of Connecticut (USA); Navid Asadizanjani, Sina Shahbazmohamadi, Mark Tehranipoor, University of Connecticut (USA); Mehdi Anwar, Univ. of Connecticut (USA) . . . . [9483-18]

Solid-state THz sources with higher power *(Invited Paper)*, Thomas W Crowe, Virginia Diodes, Inc. (USA); Steven A Retzloff, Jeffrey L Hesler, Virginia Diodes Inc (USA) . . . . [9483-19]

Lunch Break and Exhibition Time . . . . Thu 12:00 pm to 1:20 pm

SESSION 7 . . . . .THU 1:30 PM TO 3:20 PM

THz Spectroscopy

Session Chairs: **Mehdi F. Anwar,** Univ. of Connecticut (USA); **Hiroshi Ito,** Kitasato Univ. (Japan)

Nonlinear optical frequency up-conversion broadening terahertz horizons in sensitive detection *(Invited Paper)*, Kouji Nawata, Shin'ichiro Hayashi, Hiroaki Minamide, RIKEN (Japan) . . . . [9483-20]

Laminated materials characterization by terahertz kinetics spectroscopy, Anis Rahman, Aunik K. Rahman, Applied Research & Photonics, Inc. (USA) . . . . [9483-21]

Experimental determination of terahertz atmospheric absorption parameters, David M. Slocum, Thomas M. Goyette, Robert H. Giles, Univ. of Massachusetts Lowell (USA); William E. Nixon, National Ground Intelligence Ctr. (USA) . . . . [9483-22]

Possibility of the detection and identification of substance at long distance using the noisy reflected THz pulse under real conditions, Vyacheslav A. Trofimov, Svetlana A. Varentsova, Vladislav V. Trofimov, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9483-23]

THz magneto-photoresponse spectroscopy of HgTe based quantum well (gapped Dirac type electronic dispersion), Mehdi Pakmehr, Univ. at Buffalo (USA); Christoph Bruene, Laurens W. Molenkamp, Julius-Maximilians-Univ. Würzburg (Germany); Bruce D. McCombe, Univ. at Buffalo (USA). . . . . [9483-24]

SESSION 8 . . . . THU 3:50 PM TO 6:00 PM

THz Imaging

Session Chairs: **Thomas W. Crowe,** Virginia Diodes, Inc. (USA); **B. M. Azizur Rahman,** City Univ. London (United Kingdom)

Room temperature terahertz detectors and their applications *(Invited Paper)*, Jian Chen, Xuecou Tu, Lin Kang, Biaobing Jin, Peiheng Wu, Nanjing Univ. (China) . . . . [9483-25]

Performances of THz cameras with enhanced sensitivity in sub-terahertz region, Naoki Oda, Tsutomu Ishi, Seiji Kurashina, Takayuki Sudou, Takao Morimoto, Masaru Miyoshi, Kohei Doi, Hideki Goto, Tokuhito Sasaki, NEC Corp. (Japan); Goro Isoyama, Ryukou Kato, Akinori Irizawa, Keigo Kawase, The Institute of Scientific and Industrial Research (Japan) . . . . [9483-26]

MCT as sub-terahertz and infrared detector, Fiodor F. Sizov, Vyacheslav V. Zabudsky, V.E. Lashkaryov Institute of Semiconductor Physics (Ukraine); Sergey A. Dvoretsky, A.V. Rzhanov Institute of Semiconductor Physics (Russian Federation); Vladimir A. Petryiakov, Aleksandr G. Golenkov, Katerina V. Andreyeva, Zinoviia F. Tsybrii, Anna V. Shevchik-Shekera, V.E. Lashkaryov Institute of Semiconductor Physics (Ukraine); Ernesto Dieguez, Univ. Autónoma de Madrid (Spain) . . . . [9483-27]

Real-time THz beam profiling and imaging with laser-based intense THz sources, Yung Jun Yoo, Taek Il Oh, Yong Sing You, Ki-Yong Kim, Univ. of Maryland, College Park (USA). . . . . [9483-28]

Robust identification of concealed dangerous substances using THz imaging spectroscopy, Arthur D. van Rheenen, Magnus W. Haakestad, Norwegian Defence Research Establishment (Norway); Helle E. Nystad, Norwegian Univ. of Science and Technology (Norway) . . . . [9483-29]

Dark field THz camera imaging measurements, 200 GHz to 400 GHz, Andrew P. Sacco, J. Daniel Newman, Exelis Geospatial Systems (USA); Paul P. K. Lee, Univ. of Rochester (USA); Kenneth D. Fourspring, John H. Osborn, Robert D. Fiete, Exelis Geospatial Systems (USA); Mark F. Bocko, Zeljko Ignjatovic, Judith L. Pipher, Craig W. McMurtry, Xi-Cheng Zhang, Jagannath Dayalu, Univ. of Rochester (USA); Katherine Seery, Chao Zhang, Zoran Ninkov, Rochester Institute of Technology (USA) . . . . [9483-30]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

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Inspection of mechanical and electrical properties of silicon wafers using terahertz tomography and spectroscopy, Thomas Arnold, Wolfgang Mühleisen, Johannes Schicker, Christina Hirschl, Raimund Leitner, Carinthian Tech Research AG (Austria) . . . . [9483-31]

Variation of ZnMgO properties upon growth technique in THz spectrum, Abdiel Rivera, Anas Mazady, Kiarash Ahi, Mehdi Anwar, Univ. of Connecticut (USA) . . . . [9483-32]

CONFERENCE 9484

Wednesday–Friday 22–24 April 2015 • Proceedings of SPIE Vol. 9484

Compressive Sensing IV

Conference Chair: **Fauzia Ahmad,** Villanova Univ. (USA)

Program Committee: **Moeness G. Amin,** Villanova Univ. (USA); **Gonzalo R. Arce,** Univ. of Delaware (USA); **Abdesselam Salim Bouzerdoum,** Univ. of Wollongong (Australia); **Michael J. DeWeert,** BAE Systems (USA); **Matthew A. Herman,** InView Technology Corp. (USA); **Eric L. Mokole,** U.S. Naval Research Lab. (USA); **Ram M. Narayanan,** The Pennsylvania State Univ. (USA); **Dimitris A. Pados,** Univ. at Buffalo (USA); **Athina P. Petropulu,** Rutgers, The State Univ. of New Jersey (USA); **Zhijun G. Qiao,** The Univ. of Texas-Pan American (USA); **Ervin Sejdic,** Univ. of Pittsburgh (USA); **Lei (Leslie) Ying,** Univ. at Buffalo (USA)

WEDNESDAY 22 APRIL

SESSION 1. . . . . WED 3:30 PM TO 4:50 PM

Compressive Sensing for Radar

Session Chair: **Ram M. Narayanan,** The Pennsylvania State Univ. (USA)

Compressive sensing imaging for general SAR echo model based on Maxwell's equations, Bing Sun, Shuxia Li, Yufeng Cao, Zhijun G. Qiao, The Univ. of Texas-Pan American (USA) . . . . [9484-1]

Sparsity-based moving target localization using multiple dual-frequency radars, Khodour AlKadry, Fauzia Ahmad, Moeness G. Amin, Villanova Univ. (USA) . . . . [9484-2]

Cross-term free based bistatic radar system using sparse least squares, Rasim A. Sevimli, Ahmet E. Cetin, Bilkent Univ. (Turkey) . . . . [9484-3]

Multi-view TWRI scene reconstruction using a joint Bayesian sparse approximation model, Van Ha Tang, Abdesselam Bouzerdoum, Son Lam Phung, Fok Hing Chi Tivive, Univ. of Wollongong (Australia) . . . . [9484-4]

THURSDAY 23 APRIL

SESSION 2 . . . . THU 9:00 AM TO 10:20 AM

Compressive Sensing for Spectral Imaging

Session Chair: **Gonzalo R. Arce,** Univ. of Delaware (USA)

Point-spread functions for coded aperture imaging with separable doubly-Toeplitz masks, Michael J. DeWeert, BAE Systems (USA) . . . . [9484-5]

Computational imaging in a multiplexed imager with static multispectral encoding, Johann Veras, Robert R. Muise, Kevin Hines, Lockheed Martin Corp. (USA) . . . . [9484-6]

Compressive and classical hyperspectral systems: a fundamental comparison, Isaac Y. August, Adi Shay, Adrian Stern, Ben-Gurion Univ. of the Negev (Israel). . . . . [9484-7]

Compressive spectral polarization imaging with coded micropolarizer array, Chen Fu, Univ. of Delaware (USA); Henry Arguello, Univ. Industrial de Santander (Colombia); Gonzalo R. Arce, Univ. of Delaware (USA); Brian M. Sadler, U.S. Army Research Lab. (USA) . . . . [9484-8]

SESSION 3 . . . . THU 10:50 AM TO 12:10 PM

CS for Optical Imaging, Motion Imagery, and Video I

Session Chair: **Michael J. DeWeert,** BAE Systems (USA)

Recent results in single-pixel compressive imaging using selective measurement strategies *(Invited Paper)*, Matthew A. Herman, InView Technology Corp. (USA) . . . . [9484-9]

L1-PCA video surveillance, Ying Liu, Dimitris A. Pados, Univ. at Buffalo (USA) . . . . [9484-10]

Gradient-based compressive sensing for noise video reconstruction, Huihuang Zhao, Hengyang Normal Univ. (China); Shuxia Li, John Montalbo, Zhijun G. Qiao, The Univ. of Texas-Pan American (USA) . . . . [9484-11]

Lunch Break and Exhibition Time . . . . Thu 12:10 pm to 1:40 pm

SESSION 4 . . . . THU 1:40 PM TO 3:20 PM

CS Signal Processing

Session Chair: **Ervin Sejdic,** Univ. of Pittsburgh (USA)

Compressive sensing cryptographic analysis, Ponciano J. Escamilla-Ambrosio, Moises Salinas Rosales, Eleazar Aguirre-Anaya, Ctr. de Investigación en Computación (Mexico) . . . . [9484-12]

Sparsity-based DOA estimation of coherent and uncorrelated sources using transmit/receive co-prime arrays, Elie BouDaher, Fauzia Ahmad, Moeness G. Amin, Villanova Univ. (USA) . . . . [9484-13]

See-through obscurants via compressive sensing in degraded visual environment, Richard C. Lau, Ted K. Woodward, Applied Communication Sciences (USA) . . . . [9484-14]

An analysis of spectral transformation techniques on graphs, Igor Djurovic, Univ. of Montenegro (Montenegro); Ervin Sejdic, Univ. of Pittsburgh (USA); Nikola Bulatovic, Marko Simeunovic, Univ. of Montenegro (Montenegro) . . . . [9484-15]

Time-frequency signature sparse reconstruction using chirp dictionary, Yen T. H. Nguyen, Univ. of Leeds (United Kingdom) and Villanova Univ. (USA); Moeness G. Amin, Villanova Univ. (USA); Mounir Ghogho, Univ. of Leeds (United Kingdom) and Univ. Internationale de Rabat (Morocco); Des McLernon, Univ. of Leeds (United Kingdom) . . . . [9484-16]

SESSION 5 . . . . THU 3:50 PM TO 4:50 PM

CS for Optical Imaging, Motion Imagery, and Video II

Session Chair: **Matthew A. Herman,** InView Technology Corp. (USA)

Compressive line sensing imaging system using active spatial light modulation devices, Bing Ouyang, Harbor Branch Oceanographic Institute (USA) and Florida Atlantic Univ. (USA); Weilin W. Hou, U.S. Naval Research Lab. (USA); Frank M. Caimi, Fraser R. Dalgleish, Anni K. Vuorenkoski, Harbor Branch Oceanographic Institute (USA); Cuiling Gong, Texas Christian Univ. (USA); Walter Britton, Harbor Branch Oceanographic Institute (USA) . . . . [9484-17]

Compressive quantum sensing *(Invited Paper)*, John C. Howell, Gregory Howland, Daniel Lum, Univ. of Rochester (USA) . . . . [9484-18]

FRIDAY 24 APRIL

SESSION 6 . . . . FRI 8:40 AM TO 10:00 AM

CS for Acoustics, Ultrasound, and Health Monitoring of Structures

Session Chair: **Dimitris A. Pados,** Univ. at Buffalo (USA)

Sparse spectral estimation techniques for output-only modal system identification of civil engineering structures, Agathoklis Giaralis, Bamrung Tausiesakul, Kyriaki Gkoktsi, City Univ. London (United Kingdom) . . . . [9484-19]

Multimodal exploitation and sparse reconstruction for guided-wave structural health monitoring, Andrew L. Golato, Sridhar Santhanam, Fauzia Ahmad, Moeness G. Amin, Villanova Univ. (USA) . . . . [9484-20]

Seismic traces reconstruction from compressive measurements, Ana Ramirez, Gonzalo R. Arce, Univ. of Delaware (USA) . . . . [9484-21]

Group sparsity based estimation of nonstationary harmonic signals, Yimin D. Zhang, Villanova Univ. (USA) . . . . [9484-22]

SESSION 7 . . . . FRI 10:30 AM TO 11:30 AM

CS for Healthcare and Biomedical Applications

Session Chair: **Fauzia Ahmad,** Villanova Univ. (USA)

Robust architecture for wireless surface EMG sensors based on analog compressed sensing theory, Mohammadreza Balouchestani, Sri Krishnan, Ryerson Univ. (Canada). . . . . [9484-23]

Neighborhood-cost based sampling design for randomly sampled parallel MRI with low rank constrants, Wan Kim, The State Univ. of New York (USA); Leslie Ying, The State Univ. of New York (USA) . . . . [9484-24]

Advanced K-means clustering algorithm for long-term surface EMG monitoring based on compressed sensing theory, Mohammadreza Balouchestani, Sridhar Krishnan, Ryerson Univ. (Canada) . . . . [9484-25]

CONFERENCE 9485

Monday–Thursday 20–23 April 2015 • Proceedings of SPIE Vol. 9485

Thermosense: Thermal Infrared Applications XXXVII

Conference Chair: **Sheng-Jen (Tony) Hsieh,** Texas A&M Univ. (USA)

Conference Co-Chair: **Joseph N. Zalameda,** NASA Langley Research Ctr. (USA)

Program Committee: **Andrea Acosta,** Colbert Infrared Services (USA); **Nicolas Avdelidis,** National Technical Univ. of Athens (Greece); **Paolo Bison,** Consiglio Nazionale delle Ricerche (Italy); **Jeff R. Brown,** Embry-Riddle Aeronautical Univ. (USA); **Douglas Burleigh,** La Jolla Cove Consulting (USA); **Fred P. Colbert,** Colbert Infrared Services (USA); **K. Elliott Cramer,** NASA Langley Research Ctr. (USA); **Ralph B. Dinwiddie,** Oak Ridge National Lab. (USA); **Herbert Kaplan,** Honeyhill Technical Co. (USA); **Timo T. Kauppinen,** VTT Technical Research Ctr. of Finland (Finland); **Dennis H. LeMieux,** Siemens Power Generation, Inc. (USA); **Monica Lopez Saenz,** IRCAM GmbH (Germany); **Xavier P. V. Maldague,** Univ. Laval (Canada); **Gary L. Orlove,** FLIR Systems, Inc. (USA); **Beata Oswald-Tranta,** Montan Univ. Leoben (Austria); **G. Raymond Peacock,** Temperatures.com, Inc. (USA); **Piotr Pregowski,** Pregowski Infrared Services (Poland); **Ralph A. Rotolante,** Vicon Enterprises Inc. (USA); **Andres E. Rozlosnik,** SI Termografía Infrarroja (Argentina); **Morteza Safai,** The Boeing Co. (USA); **Takahide Sakagami,** Kobe Univ. (Japan); **Steven M. Shepard,** Thermal Wave Imaging, Inc. (USA); **Sami Siikanen,** VTT Technical Research Ctr. of Finland (Finland); **Gregory R. Stockton,** Stockton Infrared Thermographic Services, Inc. (USA); **Vladimir P. Vavilov,** Tomsk Polytechnic Univ. (Russian Federation); **Xiong Yu,** Case Western Reserve Univ. (USA)

ThermoSense Mission Statement

The Infrared Applications, ThermoSense conference promotes the worldwide exchange of information about the uses or applications of thermal infrared sensing, imaging and measuring instruments through papers, workshops and short-courses. Over the past thirty seven years these activities have included topics from the fundamentals of imaging and calibration to virtually all civilian applications of infrared equipment with special emphasis on problem solving and reduction to practice.

Thermosense Background

Thermosense is the oldest and largest international technical meeting focused on scientific, industrial and general uses of infrared imaging and infrared temperature measurements. Its regular printed proceedings are found in most scientific and engineering libraries, providing an unequaled depth and breadth of technical information and reference data. Further information regarding Thermosense can be found at: www.thermosense.org

MONDAY 20 APRIL

VENDOR SESSION. . . . . 1:00 PM TO 5:00 PM

The Infrared Applications: ThermoSense XXXVII

Moderators: **Andrés E. Rozlosnik,** SI Termografia Infrarroja (Argentina), and **Herb Kaplan,** Honeyhill Technical Co. (USA)

The Infrared Applications: ThermoSense XXXVII Vendor Session will be held on Monday afternoon, 20 April 2015 as part of SPIE's DSS 2015 Conference in Baltimore. The session will feature brief presentations from hardware and software vendors whose product lines impact thermal imaging applications.

Unlike the technical sessions, there are no "commercial content" restrictions in these presentations.

This event allows vendors to showcase new products on display at this year's exhibit, and provides attendees with an advance glimpse of "what's new" in thermal imaging applications.

All exhibitors are eligible to present.

The Vendor Session was started eleven years ago and has been a popular, well-attended success. It allows the busy technical conference attendees to better prioritize their time when visiting the exhibits. It also provides a relaxed atmosphere for informal conversations between vendors and conference attendees.

The session begins with 10-15 minute presentations and is followed by a reception and mixer with snacks and soft drinks.

Plan your travel to arrive early enough to get this valuable preview of evolving technology.

Any exhibitor offering products or services related to infrared sensing or imaging can participate, but vendor time slots are limited and available on a first-come first-served basis.

To register as a presenter, please provide the following:

- Name, title, affiliation and contact information for the presenter
- Title of presentation
- Brief (one line) summary of presentation content

The list of participating vendors and the content of their presentations will appear in the final program. If you are interested in participating or have any questions, please contact:

Vendors Session 2014 Moderators:

Herb Kaplan, hkaplan@earthlink.net

or **Andrés Rozlosnik**, or aer@termografia.com

VENDORS IN PRESENTATION ORDER:

Magnity Electronics (Booth 330)
New development in thermal imaging technologies at Magnity Electronics
Presenter: **Chongfei Shen,** CEO

Thermoteknix (Booth 308)
New product developments from Thermoteknix Systems Ltd.
Presenter: **Alistair Brown,** Product Manager

StingRay Optics, LLC (Booth 958)
StingRay Optics Standard Products 2015
Presenter: **Sam Wyman,** Standard Products Specialist

SCD.USA, LLC (SemiConductor Devices) (Booth 911)
Newest Products for 2015 from SCD
Presenter: **Robert McDaniel,** President and CEO SCD.USA

Xenics (Booth 825)
Low and high temperature thermographic solutions
Presenter: **Jan Vermeiren,** Technical Adviser & Business Development Manager

CONFERENCE 9485

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 1. . . . . TUE 8:00 AM TO 10:10 AM

Aerospace Applications

Session Chairs: **Xavier Maldague,** Univ. Laval (Canada); **Ralph B. Dinwiddie,** Oak Ridge National Lab. (USA)

Real time fatigue damage growth assessment of a composite 3 stringer panel using passive thermography *(Invited Paper)*, Joseph N. Zalameda, Eric R. Burke, NASA Langley Research Ctr. (USA); Michael R. Horne, National Institute of Aerospace (USA) . . . . [9485-1]

Nondestructive evaluation of aircraft coatings with infrared diffuse reflectance spectra, Michael R. Hawks, Air Force Institute of Technology (USA) and Oak Ridge Institute for Science & Education (USA); Kody A. Wilson, Air Force Institute of Technology (USA); Timothy W. C. Zens, Air Command and Staff College (USA); Adam T. Cooney, Hans G. Korth, Air Force Research Lab. (USA) . . . . [9485-2]

Comparative evaluation of aerospace composites using thermography and ultrasonic NDT techniques, Panagiotis Theodorakeas, Nicolas P. Avdelidis, Eleni Cheilakou, National Technical Univ. of Athens (Greece); Roubini Marini, Hellenic Aerospace Industry S.A. (Greece); Maria Koui, National Technical Univ. of Athens (Greece). . . . . [9485-3]

A new approach on JPSS VIIRS BCS and SVS PRT calibration, Tung R. Wang, Steve A. Marschke, Michael Borroto, Christopher M. Jones, Christopher Chovit, Raytheon Co. (USA) . . . . [9485-4]

Composites evaluation in aircraft industry through triplex IR imaging system, Bob Berry, Thermal Vision (Ireland). . . . . [9485-5]

Integration of infrared and optical imaging techniques for the nondestructive inspection of aeronautic parts, Fernando López, UFSC (Brazil); Stefano Sfarra, Univ. degli Studi dell'Aquila (Italy); Clemente Ibarra-Castanedo, Univ. Laval (Canada); Domenica Paoletti, Univ. degli Studi dell'Aquila (Italy); Xavier Maldague, Univ. Laval (Canada). . . . . [9485-6]

SESSION 2 . . . . TUE 10:40 AM TO 12:00 PM

Building Materials and Infrastructure Applications I

Session Chairs: **Jeff R. Brown,** Embry-Riddle Aeronautical Univ. (USA); **Beata Oswald-Tranta,** Montan Univ. Leoben (Austria)

Identification of moisture sources in building assemblies using IRT, Gregory B. McIntosh, Snell Infrared Canada (Canada); Antonio Colantonio, Public Works and Government Services Canada (Canada) . . . . [9485-7]

Evaluation of angle dependence in spectral emissivity of ceramic tiles measured by FT-IR, Chie Kobayashi, Nagahisa Ogasawara, Hiroyuki Yamada, Syunsuke Yamada, National Defense Academy (Japan); Takashi Kikuchi, K-Plus, Inc. (Japan) . . . . [9485-8]

Study of experimental parameters for active IRT applications in multi-layered building elements with internal defects, Catarina L. Serra, ITeCons (Portugal) and Pólo II da Univ. de Coimbra (Portugal); Nuno A. Simões, Pólo II da Univ. de Coimbra (Portugal); António Tadeu, Univ. de Coimbra (Portugal) . . . . [9485-9]

Active infrared thermographic testing with distance heating, Nagahisa Ogasawara, Hikaru Ando, Chie Kobayashi, Hiroyuki Yamada, National Defense Academy (Japan). . . . . [9485-10]

Lunch Break and Exhibition Time . . . . Tue 12:00 pm to 1:30 pm

SESSION 3 . . . . .TUE 1:30 PM TO 5:00 PM

Building Materials and Infrastructure Applications II

Session Chairs: **Beata Oswald-Tranta,** Montan Univ. Leoben (Austria); **Jeff R. Brown,** Embry-Riddle Aeronautical Univ. (USA)

Comparison of lock-in and pulse-phase thermography for defect characterization in FRP composites applied to concrete, Jeff R. Brown, Sai Harsha Chittineni, Embry-Riddle Aeronautical Univ. (USA) . . . . [9485-11]

Crack depth determination with inductive thermography, Beata Oswald-Tranta, Roland Schmidt, Montan Univ. Leoben (Austria) . . . . [9485-12]

Measurement of flaw size from thermographic data, William P. Winfree, Joseph N. Zalameda, Patricia A. Howell, NASA Langley Research Ctr. (USA) . . . . [9485-13]

Characterization of vertical cracks using ultrasound excited lock-in thermography, Arantza Mendioroz, Univ. del País Vasco (Spain); Ricardo Celorrio, Univ. de Zaragoza (Spain); Agustín Salazar, Univ. del País Vasco (Spain) . . . . [9485-14]

Automatic thermographic scanning with the creation of 3D panoramic views, Alessandro Bortolin, Gianluca Cadelano, Giovanni Ferrarini, Consiglio Nazionale delle Ricerche (Italy) . . . . [9485-15]

Comparison of step heating and modulated frequency thermography for detecting bubble defects in colored acrylic glass, Sheng-Jen Hsieh, Hongjin Wang, Texas A&M Univ. (USA) . . . . [9485-16]

Detection of pinhole pefects in optical film using thermography and artificial neural network, Sheng-Jen Hsieh, Bhavana Singh, Texas A&M Univ. (USA) . . . . [9485-17]

Testing and evaluation of concrete structures by thermal wave imaging, Ravibabu Mulaveesala, Geetika Dua, Indian Institute of Technology Ropar (India); Ghali V. Subbarao, K L Univ. (India) . . . . [9485-18]

Studying industrial-scale rack-storage fires using IR thermography, Jaap de Vries, FM Global (USA). . . . . [9485-19]

WEDNESDAY 22 APRIL

SESSION 4 . . . . WED 8:00 AM TO 10:10 AM

Detector and Sensory System Development

Session Chairs: **Joseph N. Zalameda,** NASA Langley Research Ctr. (USA); **Chien-Chon Chen,** National United Univ. (Taiwan)

Advances in infrared fibers *(Invited Paper)*, Guangming Tao, Ayman F. Abouraddy, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9485-20]

Logarithmic InGaAs detectors with global shutter and active dark current reduction, Yang Ni, New Imaging Technologies (France) . . . . [9485-21]

The fabrication of sub-micron size caesium iodide x-ray scintillator, Chien Wan Hun, Po Chun Chen, National United Univ. (Taiwan); Ker Jer Huang, Chung-Shan Institute of Science and Technology (Taiwan); Chien-Chon Chen, National United Univ. (Taiwan) . . . . [9485-22]

Swap intensified WDR CMOS module for I2/LWIR fusion, Yang Ni, New Imaging Technologies (France) . . . . [9485-23]

Highly sensitive arrayed indium-antimony nanowires for infrared detection, Po-Chun Chen, National Chiao Tung Univ. (Taiwan); Chien-Chon Chen, National United Univ. (Taiwan); Shih-Hsun Chen, National Chiao Tung Univ. (Taiwan); Chung-Yi Chou, National United Univ. (Taiwan); Sheng-Jen Hsieh, Texas A&M Univ. (USA) . . . . [9485-24]

Computational methods for improving thermal imaging for consumer devices, Colm N. Lynch, National Univ. of Ireland, Galway (Ireland) and Tessera (FotoNation) Ireland Ltd. (Ireland); Nicholas Devaney, National Univ. of Ireland, Galway (Ireland); Alexandru Drimbarean, Tessera (FotoNation) Ireland Ltd. (Ireland) . . . . [9485-25]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:10 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition

SESSION 5 . . . . WED 1:00 PM TO 3:55 PM

NDT and Signal Processing

Session Chairs: **Steven M. Shepard,** Thermal Wave Imaging, Inc. (USA); **Vladimir P. Vavilov,** Tomsk Polytechnic Univ. (Russian Federation)

Pulsed thermal NDT in tables, figures and formulas *(Invited Paper)*, Vladimir P. Vavilov, Tomsk Polytechnic Univ. (Russian Federation); Douglas Burleigh, Surf Consulting (USA) . . . . [9485-26]

Advances in thermographic signal reconstruction *(Invited Paper)*, Steven M. Shepard, Thermal Wave Imaging, Inc. (USA) . . . . [9485-27]

Principal component analysis of thermographic data *(Invited Paper)*, William P. Winfree, K. Elliott Cramer, Joseph N. Zalameda, Patricia A. Howell, Eric R. Burke, NASA Langley Research Ctr. (USA). . . . . [9485-28]

Review of pulse phase thermography *(Invited Paper)*, Clemente Ibarra-Castanedo, P. Servais, Xavier Maldague, Univ. Laval (Canada) . . . . [9485-29]

Development of self-reference lock-in thermography and its applications to nondestructive testing *(Invited Paper)*, Takahide Sakagami, Kobe Univ. (Japan). . . . . [9485-30]

A novel data processing algorithm in thermal property measurement and defect detection by using one-sided active infrared thermography, Vladimir P. Vavilov, Tomsk Polytechnic Univ. (Russian Federation) . . . . [9485-31]

Signal and image processing techniques for testing and evaluation of glass fibre reinforced polymers, Ravibabu Mulaveesala, Indian Institute of Technology Ropar (India); Juned A. Siddiqui, Indian Institute of Information Technology (India); Vanita Arora, Indian Institute of Technology Ropar (India); Ghali V. Subbarao, PDPM Indian Institute of Information Technology, Design & Manufacturing Jabalpur (India) . . . . [9485-32]

SESSION 6 . . . . WED 3:55 PM TO 5:35 PM

NDT and Materials Evaluation I

Session Chairs: **Paolo Bison,** Consiglio Nazionale delle Ricerche (Italy); **Junko Morikawa,** Tokyo Institute of Technology (Japan)

Infrared thermography, ultrasound C-scan and microscope for non-destructive and destructive evaluation of 3D carbon fiber materials: a comparative study, Hai Zhang, Univ. Laval (Canada); Marc Genest, National Research Council Canada (Canada); Francois Robitaille, Univ. of Ottawa (Canada); Simon Joncas, École de Technologie Supérieure (Canada); Xavier Maldague, Univ. Laval (Canada); Catherine Leduc, École de Technologie Supérieure (Canada); Lucas West, Univ. of Ottawa (Canada). . . . . [9485-33]

Characterization of phononic heterostructures by infrared thermography, Dimitrios A. Exarchos, Ilias Tragazikis, Ioannis E. Psarobas, Theodore E. Matikas, Univ. of Ioannina (Greece) . . . . [9485-34]

Superimpose methods for uncooled infrared camera applied to the micro-scal thermal characterization of composite materials, Junko Morikawa, Tokyo Institute of Technology (Japan) . . . . [9485-35]

A numerical approach for testing and evaluation of mild steel material by thermal wave imaging, Ravibabu Mulaveesala, Geetika Dua, Indian Institute of Technology Ropar (India); Ghali V. Subbarao, K L Univ. (India) . . . . . . [9485-36]

Characterization of nuclear graphite elastic properties using laser ultrasonic methods, Fan W. Zeng, Karen Han, Lauren R. Olasov, James B. Spicer, Johns Hopkins Univ. (USA); Nidia C. Gallego, Cristian I. Contescu, Oak Ridge National Lab. (USA). . . . . [9485-37]

THURSDAY 23 APRIL

SESSION 7 . . . . THU 8:00 AM TO 10:00 AM

Manufacturing and Processing Industries

Session Chairs: **Andres E. Rozlosnik,** SI Termografía Infrarroja (Argentina); **Jian Chen,** Oak Ridge National Lab. (USA)

IR-based spot weld NDT in automotive applications, Jian Chen, Zhili Feng, Oak Ridge National Lab. (USA) . . . . [9485-38]

Laser beam welding quality monitoring system based in high-speed (10 kHz max) uncooled MWIR imaging sensors, Rodrigo Linares, Germán Vergara, Carlos Fernández, Luis Gómez, María González-Camino, Raúl Gutiérrez, María T. Montojo, Víctor Villamayor, Arturo Baldasano, New Infrared Technologies, S.L. (Spain). . . . . [9485-39]

Comparison of the insulation property of an innovative material and a traditional one by infrared thermography, Paolo Bison, Alessandro Bortolin, Gianluca Cadelano, Giovanni Ferrarini, Consiglio Nazionale delle Ricerche (Italy) . . . . [9485-40]

Thermographic investigation of luminescent barium borate glasses for white-LED applications, Florian Wagner, Fachhochschule Südwestfalen (Germany); Peter Nolte, Fraunhofer Application Ctr. for Inorganic Phosphors (Germany); Stefan Schweizer, Fachhochschule Südwestfalen (Germany) and Fraunhofer Application Ctr. for Inorganic Phosphors (Germany) . . . . . . [9485-41]

About infrared scanning of photovoltaic solar plant, Timo T. Kauppinen, P. E. Panouillot, Sami Siikanen, VTT Technical Research Ctr. of Finland (Finland); E. Athanasakou, P. Baltas, B. Nikopoulous, Euditi (Greece) . . [9485-42]

The TEMPS program at NIST and its implications for optical properties metrology of laser-matter interaction, Sergey Mekhontsev, Leonard M. Hanssen, Steven E. Grantham, Weston L. Tew, National Institute of Standards and Technology (USA). . . . . [9485-43]

SESSION 8 . . . . THU 10:30 AM TO 11:50 AM

NDT and Materials Evaluation II

Session Chairs: **Takahide Sakagami,** Kobe Univ. (Japan); **Fred P. Colbert,** Colbert Infrared Services, Inc. (USA)

Three-dimensional non-destructive testing (NDT) in the infrared spectrum, Moulay A. Akhloufi, Univ. Laval (Canada) and Ctr. of Robotics and Vision (Canada); Yannis Guyon, Univ. de Technologie de Belfort-Montbéliard (France); Abdelhakim Bendada, Clemente-Ibarra Castenado, Univ. Laval (Canada) . . . . [9485-44]

Thermographic inspection of external thermal insulation systems with mechanical fixing, Nuno A. Simões, Maria Simões, Catarina L. Serra, António Tadeu, Pólo II da Univ. de Coimbra (Portugal) . . . . [9485-45]

Thermal diffusivity estimation with quantitative pulsed phase thermography, Juan Esteban Ospina, Juan Felipe Florez, Hernan Dario Benitez, Pontificia Univ. Javeriana, Cali (Colombia) . . . . [9485-46]

Analysis of the relative merits of the 3–5 μm and the 8–12 μm spectral bands using detected thermal contrast, Sean M. Stewart, Nazarbayev Univ. (Kazakhstan) . . . . [9485-47]

Lunch Break and Exhibition Time . . . . Thu 11:50 am to 1:20 pm

SESSION 9 . . . . THU 1:20 PM TO 3:00 PM

Detection of Gas and Leaks

Session Chairs: **Vladimir P. Vavilov,** Tomsk Polytechnic Univ. (Russian Federation); **Richard Y. Chiou,** Drexel Univ. (USA)

Broadband, multispectral and hyperspectral thermal infrared imaging of gases: a systematic comparison, Alexandrine Huot, Marc-André Gagnon, Karl-Alexandre Jahjah, Pierre Tremblay, Simon Savary, Vincent Farley, Philippe Lagueux, Éric Guyot, Martin Chamberland, Telops (Canada). . . . . [9485-48]

Thermal imaging of microfluidic systems as a model for investigating energy efficiency, Richard Y. Chiou, Michael Mauk, Drexel Univ. (USA); Tzu-Liang B. Tseng, The Univ. of Texas at El Paso (USA) . . . . [9485-49]

Spectrum infrared transmission study of water spray, Zhongwei Chen, Li Zhang, Naval Academy of Armament (China) . . . . [9485-50]

Gas and flame detection and identification using uncooled MWIR imaging sensors, Rodrigo Linares, Germán Vergara, Carlos Fernández, Luis Gómez, María González-Camino, Raúl Gutiérrez, María T. Montojo, Víctor Villamayor, Arturo Baldasano, New Infrared Technologies, S.L. (Spain) . . . . [9485-51]

Detection of seal contamination in heat sealed food packaging based on active infrared thermography, Karlien D'huys, Wouter Saeys, Bart De Ketelaere, Katholieke Univ. Leuven (Belgium). . . . . [9485-52]

SESSION 10 . . . . THU 3:30 PM TO 4:50 PM

Biological/Medical Applications

Session Chairs: **Timo T. Kauppinen,** VTT Technical Research Ctr. of Finland (Finland); **Ralph A. Rotolante,** Vicon Infrared (USA)

Observation of temperature trace, induced by changing of temperature inside the human body, on the human body skin using commercially available IR camera, Vyacheslav A. Trofimov, Vladislav V. Trofimov, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9485-53]

Mass screening for infectious disease containment and pandemic outbreaks: misconceptions, Peter Leando, Compix Inc. (USA). . . . . . [9485-54]

3D medical thermography device, Peyman Moghadam, Commonwealth Scientific and Industrial Research Organisation (Australia). . . . . [9485-55]

Cow's body region detection using a visual approach on thermal images, Julien R. Fleuret, Univ. Laval (Canada) . . . . [9485-56]

AWARD CEREMONY AND BUSINESS MEETING. . . . . 4:50 PM TO 5:20 PM

Session Chairs: **Sheng-Jen Hsieh,** Texas A&M Univ. (USA); **Joseph N. Zalameda,** NASA Langley Research Ctr. (USA)

The Best Paper Award certificate and prize, a FLIR One thermal camera, will be presented.

Business meeting agenda items

1. Welcome new attendees
2. Present conference statistics (number of sessions, papers, attendees)
3. Nominations and voting for incoming co-chair for 2015
4. Discuss names to be added or dropped from steering committee membership. There will be a separate vote for each proposed change.
5. Welcome the incoming chair
6. Wrap up conference highlights of Thermosense XXXVII.

INTERACTIVE POSTER SESSION THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Distinguishability of sensor fault from system fault, Morteza Taiebat, Farrokh Sassani, The Univ. of British Columbia (Canada) . . . . [9485-57]

CONFERENCE 9486

Monday–Friday 20–24 April 2015 • Proceedings of SPIE Vol. 9486

Advanced Environmental, Chemical, and Biological Sensing Technologies XII

Conference Chairs: **Tuan Vo-Dinh,** Fitzpatrick Institute for Photonics, Duke Univ. (USA); **Robert A. Lieberman,** Lumoptix LLC (USA); **Günter G. Gauglitz,** Eberhard Karls Univ. Tübingen (Germany)

Program Committee: **Zane A. Arp,** GlaxoSmithKline (USA); **Francesco Baldini,** Istituto di Fisica Applicata Nello Carrara (Italy); **Luigi Campanella,** Univ. degli Studi di Roma La Sapienza (Italy); **Jesus Delgado Alonso,** Intelligent Optical Systems, Inc. (USA); **Franz Ludwig Dickert,** Univ. Wien (Austria); **Dennis K. Killinger,** Univ. of South Florida (USA); **Heinz-Detlef Kronfeldt,** Technische Univ. Berlin (Germany); **Robert Lascola,** Savannah River National Lab. (USA); **Edgar A. Mendoza,** Redondo Optics, Inc. (USA); **Anna Grazia Mignani,** Istituto di Fisica Applicata Nello Carrara (Italy); **Klaus Schäfer,** Karlsruher Institut für Technologie (Germany); **David L. Stokes,** EOIR Technologies (USA)

MONDAY 20 APRIL

SESSION 1. . . . . .MON 9:00 AM TO 10:00 AM

Biosensors I

Session Chair: **Tuan Vo-Dinh,**
Fitzpatrick Institute for Photonics, Duke Univ. (USA)

Highly sensitive detection of sulfadimidine in water and dairy products by using a planar waveguide evanescent wave biosensor, Lanhua Liu, Xiaohong Zhou, Weiqi Xu, Baodong Song, Hanchang Shi, Tsinghua Univ. (China) . [9486-1]

Detection of virus DNA by a surface-enhanced Raman scattering biosensor, Nianqiang Wu, West Virginia Univ. (USA). . . . . [9486-2]

iSERS: tissue-based cancer diagnostics using rationally designed plasmonic nanoparticles, Sebastian Schlücker, Yuying Zhang, Univ. Duisburg-Essen (Germany) . . . . [9486-3]

SESSION 2 . . . . MON 10:25 AM TO 11:45 AM

Biosensors II

Session Chair: **David L. Stokes,** EOIR Technologies (USA)

Label free impedance detection of different biomarkers using a nanobio sensor array, Rahim Esfandyarpour, Ronald W. Davis, Zahra Koochak, Stanford Univ. (USA) . . . . [9486-4]

Light-directed functionalization methods for high-resolution optical fiber based biosensors, Leyla N. Kahyaoglu, Rajtarun Madangopal, Jenna L. Rickus, Purdue Univ. (USA) . . . . [9486-5]

Plasmonic-biosilica SERS sensors for ultra-sensitive immuno-assay detection, Jing Yang, Le Zhen, Fanghui Ren, Gregory L. Rorrer, Alan X. Wang, Oregon State Univ. (USA) . . . . [9486-6]

Plasmonics-active gold nanostars for chemical and biological sensing using SERS detection, Yang Liu, Andrew M. Fales, Hsiangkuo Yuan, Tuan Vo-Dinh, Duke Univ. (USA). . . . . [9486-7]

Lunch Break . . . . .Mon 11:45 am to 1:15 pm

SESSION 3 . . . . .MON 1:15 PM TO 2:55 PM

Advanced Sensing Technologies

Session Chairs: **Bernd Sumpf,** Ferdinand-Braun-Institut (Germany); **Martin Maiwald,** Ferdinand-Braun-Institut (Germany)

Surface-enhanced Raman scattering sensors on guided-mode resonance gratings, Jing Yang, Xinyuan Chong, Fanghui Ren, Alan X. Wang, Oregon State Univ. (USA) . . . . [9486-8]

On-chip silicon photonic thermometers: from waveguide Bragg grating to ring resonators sensors, Nikolai N. Klimov, Sunil Mittal, National Institute of Standards and Technology (USA) and Univ. of Maryland, College Park (USA) and Joint Quantum Institute (USA); Michaela Berger, Zeeshan Ahmed, National Institute of Standards and Technology (USA). . . . . [9486-9]

Gold nanostars as building blocks for multiplexed chemical and biological sensing platforms, Laura Fabris, Rutgers, The State Univ. of New Jersey (USA); A. Swarnapali De Silva Indrasekara, Rice Univ. (USA) and Rutgers, The State Univ. of New Jersey (USA); Roney Thomas, Rutgers, The State Univ. of New Jersey (USA) . . . . [9486-10]

Mid-infrared opto-nanofluidics for label-free on-chip chemical sensing, Pao T. Lin, Massachusetts Institute of Technology (USA) . . . . [9486-11]

Shifted excitation surface-enhanced Raman difference spectroscopy for ex vivo sensing of plasmonic nanoprobes, Martin Maiwald, Ferdinand-Braun-Institut (Germany); Janna K. Register, Andrew M. Fales, Duke Univ. (USA); Götz Erbert, Günther Tränkle, Ferdinand-Braun-Institut (Germany); Tuan Vo-Dinh, Duke Univ. (USA); Bernd Sumpf, Ferdinand-Braun-Institut (Germany). . [9486-12]

SESSION 4 . . . . .MON 2:55 PM TO 5:00 PM

Chemical Sensing and Analysis

Session Chair: **Anna Grazia Mignani,**
Istituto di Fisica Applicata Nello Carrara (Italy)

Enabling optical polarization sensing methods with liquid crystals, Paul Searcy, Daniel Phipps, Erika Petrak, Chris A. Toomey, Thomas G. Baur, Meadowlark Optics, Inc. (USA) . . . . [9486-13]

Dispersive Raman spectroscopy excited at 1064nm to classify the botanic origin of honeys from calabria and quantify their sugar profile, Anna G. Mignani, Leonardo Ciaccheri, Andrea A. Mencaglia, Istituto di Fisica Applicata Nello Carrara (Italy); Rosa Di Sanzo, Sonia Carabetta, Maria Teresa Russo, Univ. Mediterranea di Reggio Calabria (Italy) . . . . [9486-14]

FTIR monitoring of methane from a local landfill, Scott W. Reeve, Tiffani Johnson, Arkansas State Univ. (USA) . . . . [9486-15]

Solutions for continuous in-situ pathlength calibration of integrating sphere based gas cells, Sarah Bergin, Jane Hodgkinson, Daniel Francis, Ralph P. Tatam, Cranfield Univ. (United Kingdom) . . . . [9486-16]

Real-time measurement of the NO2 concentration in ambient air using a multi-mode diode laser and cavity enhanced multiple line integrated absorption spectroscopy, Michael Fernez, Andreas Karpf, Gottipaty N. Rao, Adelphi Univ. (USA) . . . . [9486-17]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 5 . . . . TUE 8:30 AM TO 10:10 AM

Standoff Atmospheric Monitoring

Session Chair: **Robert A. Lieberman,** Lumoptix, LLC (USA)

Active stand-off detection of gas leaks using an open-path quantum cascade laser sensor in a backscatter configuration, Adrian Diaz, The City Univ. of New York (USA); Benjamin P. Thomas, NOAA-CREST (USA); Paulo C. Castillo, Brookhaven National Lab. (USA); Barry M. Gross, Fred Moshary, NOAA-CREST (USA) . . . . [9486-18]

Monitoring urban atmospheric ozone and ethylene remote sensing by infrared DIAL, Taieb Gasmi Cherifi, Saint Louis Univ. Madrid Campus (Spain) . . . . [9486-19]

Demonstration of aerosol and chemical cloud tracking using NIR DIAL (differential absorption lidar): PM2.5, CO_2 and CH4, Michael D. Wojcik, Space Dynamics Lab. (USA); Blake G. Crowther, Synopsys, Inc. (USA); Robert Lemon, Space Dynamics Lab. (USA); Zheng Yang, Quamrul Huda, Long Fu, Prasad Valupadas, AEMERA (Canada); Allan Chambers, Alberta Innovates Technology Futures (Canada) . . . . [9486-20]

Combined microphone array and lock-in amplifier operations for outdoor photo-acoustic sensing, Mohammad M. Islam, Univ. of Maryland, Baltimore County (USA); Joshua A. Lay, Univ. of Maryland, Baltimore (USA); Chen-Chia Wang, Sudhir B. Trivedi, Brimrose Corp. of America (USA); Jacob B. Khurgin, Johns Hopkins Univ. (USA); Fow-Sen Choa, Univ. of Maryland, Baltimore County (USA) . . . . [9486-21]

Standoff detection of trace chemicals with laser dispersion spectrometer, Michal P. Nikodem, Wroclaw Research Ctr. EIT+ (Poland) . . . . [9486-22]

SESSION 6 . . . . TUE 10:40 AM TO 12:00 PM

Sensing Methods and Enabling Technologies

Session Chair: **David L. Stokes,** EOIR Technologies (USA)

Microfluidics for spectrochemical applications, R. Shatford, D. Kim, Vassili Karanassios, Univ. of Waterloo (Canada) . . . . [9486-23]

Multispectral light scattering imaging and multivariate analysis of airborne particulates, Stephen Holler, Charles R. Skelsey, Fordham Univ. (USA); Stephen D. Fuerstenau, SDF Consulting (USA) . . . . [9486-24]

Universal optical platform for monitoring of bioprocess variables, Neha R. Sardesai, Govind Rao, Yordan Kostov, Univ. of Maryland, Baltimore County (USA) . . . . [9486-25]

Prediction of carp aggregation based on sensory data, Yu Liang, Chao Wu, The Univ. of Tennessee at Chattanooga (USA) . . . . [9486-26]

INTERACTIVE POSTER SESSION

TUESDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Polymethyl-methacrylate nanoparticles as carrier for theranostic agents into cells, Ambra Giannetti, Barbara Adinolfi, Istituto di Fisica Applicata Nello Carrara (Italy); Mario Pellegrino, Univ. di Pisa (Italy); Giovanna Sotgiu, Istituto per la Sintesi Organica e la Fotoreattività (Italy); Sara Tombelli, Cosimo Trono, Istituto di Fisica Applicata Nello Carrara (Italy); Greta Varchi, Istituto per la Sintesi Organica e la Fotoreattività (Italy); Francesco Baldini, Istituto di Fisica Applicata Nello Carrara (Italy) . . . . [9486-27]

Global nuclear radiation monitoring using plants, Mohammad M. Islam, Carlos Romero-Talamas, Yordan Kostov, Univ. of Maryland, Baltimore County (USA); Wanpeng Wang, Zhongchi Liu, Univ. of Maryland, College Park (USA); Daniel S. Hussey, Eli Baltic, David L. Jacobson, National Institute of Standards and Technology (USA); Fow-Sen Choa, Univ. of Maryland, Baltimore County (USA) . . . . [9486-28]

A plastic optical fiber biosensor for e. coli, Domingos M. C. Rodrigues, Regina C. S. B. Allil, Vanessa M. Queiroz, Rafaela N. Lopes, Marcelo M. Werneck, Univ. Federal of Rio de Janeiro (Brazil) . . . . [9486-29]

Fabrication and characterization of Pd nanocube-reduced graphene oxide composite based hydrogen sensor, Duy-Thach Phan, Gwiy Sang Chung, Univ. of Ulsan (Korea, Republic of) . . . . [9486-30]

Oil and gas deposits determination by ultraspectral lidar, Alexsandr S. Grishkanich, Alexsandr P. Zhevlakov, Sergey V. Kascheev, Victor G. Bespalov, National Research Univ. of Information Technologies, Mechanics and Optics (Russian Federation); Alexsandr A. Il'inskiy, All Russian Petroleum Research Exploration Institute (Russian Federation); Dmitriy V. Kosachiov, Gazprom (Russian Federation) . . . . [9486-31]

Lidar for monitoring methane hydrate in the arctic permafrost, Alexsandr S. Grishkanich, Alexsandr P. Zhevlakov, Sergey V. Kascheev, Victor G. Bespalov, Valentin V. Elizarov, National Research Univ. of Information Technologies, Mechanics and Optics (Russian Federation); Alexsandr Gusarov, Belgian Nuclear Research Ctr. (Belgium) . . . . [9486-32]

Monitoring radioactive contamination by hyperspectral lidar, Alexsandr S. Grishkanich, Alexsandr P. Zhevlakov, Sergey V. Kascheev, Valentin V. Elizarov, National Research Univ. of Information Technologies, Mechanics and Optics (Russian Federation); Alexsandr Gusarov, Belgian Nuclear Research Ctr. (Belgium); Sergey K. Vasiev, The State Atomic Energy Corp. ROSATOM (Russian Federation) . . . . [9486-33]

Chemical agent registration method on the basis of surface optical sensitization and surface plasmon resonance, Sergei Vinogradov, Michail Kononov, A. M. Prokhorov General Physics Institute (Russian Federation) . . . . [9486-34]

Fabrication and characterization of Ag/ZnO nanoparticles-reduced graphene oxide hybrid based acetylene sensor, A .S. M. Iftekhar Uddin, Gwiy Sang Chung, Univ. of Ulsan (Korea, Republic of) . . . . [9486-35]

Quality control in the recycling stream of PVC cable waste by hyperspectral imaging, Silvia Serranti, Valentina Luciani, Giuseppe Bonifazi, Univ. degli Studi di Roma La Sapienza (Italy) . . . . [9486-36]

FRIDAY 24 APRIL

SESSION 7 . . . . FRI 4:00 PM TO 6:00 PM

Laser Chemical Detection

Joint Session with Conferences 9467, 9455, 9486

Session Chair: **Michael K. Rafailov,** The Reger Group (USA)

Broadband mid-IR frequency comb source for standoff chemical detection *(Invited Paper)*, Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9467-94]

Standoff trace detection of explosives with Infrared hyperspectral imagery *(Invited Paper)*, Frank Fuchs, Stefan Hugger, Jan-Philip Jarvis, Quankui K. Yang, Ralf Ostendorf, Christian Schilling, Wolfgang Bronner, Raschid Driad, Rolf Aidam, Joachim Wagner, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany) . . . . [9467-95]

Spectral shifted background references for QCL based mid infrared standoff spectroscopy *(Invited Paper)*, Charles W. Van Neste, Thomas G. Thundat, Univ. of Alberta (Canada) . . . . [9467-96]

Toward the realization of a compact chemical sensor platform using quantum cascade lasers *(Invited Paper)*, Ellen L. Holthoff, Paul M. Pellegrino, Logan S. Marcus, U.S. Army Research Lab. (USA) . . . . [9467-97]

Detection of trace explosives on relevant substrates using a mobile platform for photothermal infrared imaging spectroscopy (PT-IRIS) *(Invited Paper)*, Christopher A. Kendziora, Robert Furstenberg, Michael R. Papantonakis, Viet Nguyen, Jeff M. Byers, R. Andrew McGill, U.S. Naval Research Lab. (USA) . . . . [9467-98]

Standoff detection of chemical and biological threats using miniature widely tunable QCLs *(Invited Paper)*, Petros Kotidis, Erik R. Deutsch, Anish K. Goyal, Block Engineering, LLC (USA) . . . . [9467-99]

SESSION 8 . . . . .FRI 6:00 PM TO 7:00 PM

Quantum Cascade Lasers

Joint Session with Conferences 9467, 9455, 9486

Session Chair: **Michael K. Rafailov,** The Reger Group (USA)

Recent progress in quantum cascade external cavity laser systems optimized for mid-IR sensing applications *(Invited Paper)*, David B. Arnone, Leigh J. Bromley, David B. Caffey, William B. Chapman, Timothy Day, Allen Priest, Daylight Solutions Inc. (USA); Charles C. Harb, The Univ. of New South Wales (Australia) . . . . [9467-100]

Recent results on performance optimization of QCLs for consumption, spectral coverage and power *(Invited Paper)*, Antoine Müller, Richard Maulini, Stéphane Blaser, Alfredo Bismuto, Tobias Gresch, Romain Terazzi, Alpes Lasers SA (Switzerland) . . . . [9467-101]

High power MWIR quantum cascade lasers and their use in intra-cavity THz room temperature generation *(Invited Paper)*, Mariano Troccoli, AdTech Optics, Inc. (USA) . . . . [9467-102]

CONFERENCE 9487

Thursday–Friday 23–24 April 2015 • Proceedings of SPIE Vol. 9487

Smart Biomedical and Physiological Sensor Technology XII

Conference Chairs: **Brian M. Cullum,** Univ. of Maryland, Baltimore County (USA); **Eric S. McLamore,** Univ. of Florida (USA)

Program Committee: **Troy A. Alexander,** U.S. Army Research Lab. (USA); **Christopher Anton,** Episensors, Inc. (USA); **Karl S. Booksh,** Univ. of Delaware (USA); **Jonathan C. Claussen,** U.S. Naval Research Lab. (USA); **Mikella E. Farrell,** U.S. Army Research Lab. (USA); **Amethist S. Finch,** U.S. Army Research Lab. (USA); **Claudia Gärtner,** microfluidic ChipShop GmbH (Germany); **Christopher D. Geddes,** Univ. of Maryland, Baltimore (USA); **Ilko K. Ilev,** U.S. Food and Drug Administration (USA); **Douglas Kiehl,** Eli Lilly and Co. (USA); **T. Joshua Pfefer,** U.S. Food and Drug Administration (USA); **Noriko Satake,** UC Davis Medical Ctr. (USA); **Shiv K. Sharma,** Univ. of Hawai'i (USA); **Mohan Singh,** VBS Purvanchal Univ. (India); **Narsingh B. Singh,** Univ. of Maryland, Baltimore County (USA); **Ryan J. White,** Univ. of Maryland, Baltimore County (USA)

THURSDAY 23 APRIL

SESSION 1. . . . . THU 9:40 AM TO 11:20 AM

Advances in Microfluidic Analyses

Session Chairs: **Douglas Kiehl,** Eli Lilly and Co. (USA); **Claudia Gärtner,** microfluidic ChipShop GmbH (Germany)

Smartphone based paper/plastic hybrid microfluidic chemiluminescence sensor for nanomolar peroxide detection, Renny E. Fernandez, Elise Lebiga, Southern Methodist Univ. (USA); Mayank Ahuja, Plano East Senior High School (USA); Alexander Lippert, Ali Beskok, Southern Methodist Univ. (USA). . [9487-1]

Microsystem integrated immunosensor for the detection of the bioterrorist agent francisella tularensis, Ciara K. O'Sullivan, Univ. Rovira i Virgili (Spain) . . . . [9487-2]

Sensor enhanced microfluidic devices for cell based assays and organs on chip, Claudia Gärtner, Holger Becker, Ingo Schulz, Tobias Jahn, Cäcilia Freund, microfluidic ChipShop GmbH (Germany) . . . . [9487-3]

Integrated microsystem for multiplexed genosensor detection of biowarfare agents, Samuel Dulay, Univ. Rovira i Virgili (Spain); Rainer Gransee, Fraunhofer ICT-IMM (Germany); Sandra Julich, Herbert Tomaso, Friedrich-Loeffler-Institut (Germany); Ciara K. O'Sullivan, Univ. Rovira i Virgili (Spain) and Institució Catalana de Recerca i Estudis Avançats (Spain). . . . . [9487-4]

Ultrafast real-time PCR with integrated melting curve analysis and duplex capacities using a low-cost polymer lab-on-a-chip system, Rainer Gransee, Fraunhofer ICT-IMM (Germany); Tristan Schneider, Univ. of Applied Sciences Wiesbaden (Germany); Deniz Elyorgun, Fachhochschule Bingen (Germany); Tobias Schunck, Christian Winkler, Julian Hoeth, Fraunhofer ICT-IMM (Germany) . . . . [9487-5]

Lunch Break and Exhibition Time . . . . Thu 11:20 am to 1:10 pm

SESSION 2 . . . . THU 1:10 PM TO 2:50 PM

Electrochemical/ Electro-Luminescent Sensing

Session Chairs: **Claudia Gärtner,** microfluidic ChipShop GmbH (Germany); **Ryan J. White,** Univ. of Maryland, Baltimore County (USA)

Biocompatible, membrane coated electrochemical aptamer-based sensors for long-term monitoring in complex sample matrices, Lauren R. Schoukroun-Barnes, Ethan Glaser, Ryan J. White, Univ. of Maryland, Baltimore County (USA). . . . . [9487-6]

Rapid detection of listeria spp. using an internalin-a aptasensor based on carbon-metal nanohybrid structures, Diana C. Vanegas-Gamboa, Univ. of Florida (USA) and Univ. del Valle (Colombia); Yue Rong, Neil Schwalb, Univ. of Florida (USA); Katherine D. Hills, Carmen L. Gomes, Texas A&M Univ. (USA); Eric S. McLamore, Univ. of Florida (USA) . . . . [9487-7]

Electrochemical detection of francisella tularensis genomic DNA using solid-phase recombinase polymerase amplification, Ciara K. O'Sullivan, Univ. Rovira i Virgili (Spain) . . . . [9487-8]

ECL detection of francisella tularensis DNA target based on "switch-on-off" strategy with surface confinement of the system using diazonium salt as a molecular linker, Mabel Torrens, Mayreli Ortiz, Ciara K. O'Sullivan, Univ. Rovira i Virgili (Spain). . . . . [9487-9]

Electrochemiluminescence genosensor for multiplex detection of pathogen species, Ciara K. O'Sullivan, Univ. Rovira i Virgili (Spain) . . . . [9487-10]

SESSION 3 . . . . THU 3:20 PM TO 5:00 PM

Regulation and Monitoring

Session Chairs: **Douglas Kiehl,** Eli Lilly and Co. (USA); **T. Joshua Pfefer,** U.S. Food and Drug Administration (USA)

Dynamic analysis and performance evaluation of the BIAcore surface plasmon resonance biosensor, Juan F. Ospina, Univ. EAFIT (Colombia) . . . . [9487-11]

Implementation of a novel fiber-optic Fourier transform infrared (FO-FTIR) spectroscopy approach for non-contact and label-free sensing of biochemical contamination, Moinuddin Hassan, Elizabeth Gonzalez, Victoria M. Hitchins, Ilko K. Ilev, U.S. Food and Drug Administration (USA) . . . . [9487-12]

Process patent protection: protecting biopharmaceutical intellectual property via natural-abundance stable isotopes *(Invited Paper)*, John P. Jasper, Nature's Fingerprint (USA) and Molecular Isotope Technologies, LLC (USA) . . . . [9487-13]

Remote characterization of biological specimens using all-optical frequency-domain photoacoustic microscopy, Ashwin Sampathkumar, Riverside Research Institute (USA) . . . . [9487-14]

3D noninvasive, high-resolution imaging using a novel photoacoustic tomography system (pat) and rapid wavelength-cycling lasers, Ashwin Sampathkumar, Riverside Research Institute (USA); Marc Klosner, Gary Chan, Chunbai Wu, Donald F. Heller, Light Age, Inc. (USA) . . . . [9487-15]

INTERACTIVE POSTER SESSION

THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

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Speckle-correlation imaging through highly scattering turbid media with compressed sensing theory, Xiaopeng Shao, Weijia Dai, Tengfei Wu, Huijuan Li, Lin Wang, Xidian Univ. (China) . . . . [9487-33]

Imaging through turbid media via sparse representation: imaging quality comparison of three projection matrices, Xiaopeng Shao, Huijuan Li, Tengfei Wu, Weijia Dai, Lin Wang, Xidian Univ. (China). . . . . [9487-34]

A spectral method of color modeling and calibration for optical imaging systems, Rui Gong, Xiaopeng Shao, Lin Wang, Xidian Univ. (China); Xun Yu, Xun Yu, Baoyuan Liu, Xi'an Technological Univ. (China); Feng Han, Xi'an Univ. of Technology (China) . . . . [9487-35]

Leptospirosis risk depending on the distance to a potential source of infection, Erica Tatiana E. Loaiza Echeverri, Doracelly D. Hincapie-Palacio, Jesus J. Ochoa, Univ. de Antioquia (Colombia); Juan F. Ospina, Univ. EAFIT (Colombia) . . . . [9487-36]

Printing graphene-based inks on flexible substrates for biosensor applications, Jonathan C. Claussen, Iowa State Univ. (USA) . . . . [9487-37]

FRIDAY 24 APRIL

SESSION 4 . . . . FRI 8:20 AM TO 10:00 AM

Recent Developments in Biological SERS Sensing

Session Chairs: **Mikella E. Farrell,** U.S. Army Research Lab. (USA); **Ilko K. Ilev,** U.S. Food and Drug Administration (USA)

Flexible SERS-based substrates: challenges and opportunities toward an Army relevant universal sensing platform *(Invited Paper)*, Mikella E. Farrell, U.S. Army Research Lab. (USA); Srikanth Singamaneni, Washington Univ. in St. Louis (USA); Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . . [9487-16]

Surface-enhanced Raman scattering from living cells: from differentiating healthy and cancerous cell to cytotoxicity assessment *(Invited Paper)*, Mustafa Culha, Gamze Kuku, Melike Saricam, Sevda Mert, Yeditepe Univ. (Turkey) . . . . [9487-17]

Quantitative detection and SERS, Amanda J. Haes, The Univ. of Iowa (USA) . . . . [9487-18]

Functionalized paper SERS (P-SERS) substrates for selective targeting of analytes in complex samples, Wei W. Yu, Eric P. Hoppmann, Diagnostic anSERS, Inc. (USA) . . . . [9487-19]

Large area super-resolution chemical imaging via rapid dithering of a nanoprobe, Eric R. Languirand, Brian M. Cullum, Univ. of Maryland, Baltimore County (USA). . . . . [9487-20]

SESSION 5 . . . . FRI 10:20 AM TO 12:20 PM

Smart Materials for Biological and Biomedical Sensing

Session Chairs: **Jonathan C. Claussen,** U.S. Naval Research Lab. (USA); **Narsingh B. Singh,** Univ. of Maryland, Baltimore County (USA)

Bridgman growth of lead selenoiodide for multifunctional detectors, David House, Reecha Suri, Christopher Cooper, Brad Arnold, Fow-Sen Choa, Lisa Kelly, Univ. of Maryland, Baltimore County (USA); Liliana Braescu, Institut National de la Recherche Scientifique (Canada); Narsingh B. Singh, Univ. of Maryland, Baltimore County (USA) . . . . [9487-21]

Characterization of the role of oxide spacers in multilayer-enhanced SERS probes, Pietro Strobbia, Brian M. Cullum, Univ. of Maryland, Baltimore County (USA) . . . . [9487-22]

Optical nanosystems for biomolecular reaction studies *(Invited Paper)*, Jing Pan, Tae-Gon Cha, Jong Hyun Choi, Purdue Univ. (USA) . . . . [9487-23]

From materials science to next generation sensing using synthetic and engineered peptide technology *(Invited Paper)*, Dimitra N. Stratis-Cullum, U.S. Army Research Lab. (USA) . . . . [9487-24]

Enhancing enzymatic efficiency by attachment to semiconductor nanoparticles for biosensor applications *(Invited Paper)*, Joyce C. Breger, Scott Walper, Eunkeu Oh, Kimihiro Susumy, Michael H. Stewart, Jeffrey Deschamps, Mario G. Ancona, Igor L. Medintz, U.S. Naval Research Lab. (USA) . . . . [9487-25]

Structural reconfiguration of DNA origami *(Invited Paper)*, Haorong Chen, Feiran Li, Jong Hyun Choi, Purdue Univ. (USA) . . . . [9487-26]

Lunch Break . . . . Fri 12:20 pm to 1:50 pm

SESSION 6 . . . . FRI 1:50 PM TO 3:30 PM

Patient Based Monitoring

Session Chairs: **Noriko Satake,** UC Davis Medical Ctr. (USA); **Douglas Kiehl,** Eli Lilly and Co. (USA)

Automated calculation of bifurcation carotid angle for analyzing the risk of carotis plaques by using carotid ct angiographic images, Nusret Demir, Akdeniz Üniv. (Turkey); Serkan Demir, GATA Haydarpasa Training Military Hospital (Turkey) . . . . [9487-27]

Electroencephalograph (EEG) study of brain bistable illusionaaatest, Qinglei Meng, Univ. of Maryland, Baltimore County (USA); Elliot Hong, Univ. of Maryland, Baltimore (USA) and Univ. of Maryland School of Medicine (USA); Fow-Sen Choa, Univ. of Maryland, Baltimore County (USA) . . . . [9487-28]

Sensor probes and phantoms for advanced transcranial magnetic stimulation system developments, Qinglei Meng, Univ. of Maryland, Baltimore County (USA); Prashil Patel, Sudhir B. Trivedi, Brimrose Corp. of America (USA); Xiaoming Du, Elliot Hong, Univ. of Maryland, Baltimore (USA); Fow-Sen Choa, Univ. of Maryland, Baltimore County (USA) . . . . [9487-29]

A very low-cost 3D scanning system for whole-body imaging, Jeremy Straub, Scott Kerlin, Univ. of North Dakota (USA) . . . . [9487-30]

Smart clothing systems integrating contact and contactless sensors for vital signal continuous monitoring: a comparative analysis from integration and performance considerations, Isabel G. Trindade, Frederico Martins, Rui A. L. Miguel, Manuel Santos Silva, Univ. da Beira Interior (Portugal) . . . . [9487-31]

Mathematical modeling of Chikungunya fever control, Juan F. Ospina, Univ. EAFIT (Colombia). . . . . [9487-32]

CONFERENCE 9488

Tuesday–Wednesday 21–22 April 2015 • Proceedings of SPIE Vol. 9488

Sensing for Agriculture and Food Quality and Safety VII

Conference Chairs: **Moon S. Kim,** USDA Agricultural Research Service (USA); **Kuanglin Chao,** USDA Agricultural Research Service (USA); **Bryan A. Chin,** Auburn Univ. (USA)

Program Committee: **Arun K. Bhunia,** Ctr. for Food Safety Engineering, Purdue Univ. (USA); **Suming Chen,** National Taiwan Univ. (Taiwan); **Byoung-Kwan Cho,** Chungnam National Univ. (Korea, Republic of); **Stephen R. Delwiche,** USDA Agricultural Research Service (USA); **Ki-Bok Kim,** Korea Research Institute of Standards and Science (Korea, Republic of); **Naoshi Kondo,** Kyoto Univ. Graduate School of Agriculture (Japan); **Kurt C. Lawrence,** USDA Agricultural Research Service (USA); **Kangjin Lee,** National Academy of Agricultural Science (Korea, Republic of); **Alan M. Lefcourt,** USDA Agricultural Research Service (USA); **Changying (Charlie) Li,** The Univ. of Georgia (USA); **Renfu Lu,** USDA Agricultural Research Service (USA); **Bosoon Park,** USDA Agricultural Research Service (USA); **Yang Tao,** Univ. of Maryland, College Park (USA); **Yankun Peng,** China Agricultural Univ. (China); **Gang Yao,** Univ. of Missouri-Columbia (USA); **Haibo Yao,** Mississippi State Univ. (USA); **Yibin Ying,** Zhejiang Univ. (China); **Seung-Chul Yoon,** USDA Agricultural Research Service (USA)

TUESDAY 21 APRIL

SESSION 1. . . . . .TUE 1:00 PM TO 3:20 PM

Sensing for Food Quality and Safety I

Session Chairs: **Howard Clyde Wikle III,** Auburn Univ. (USA); **Christoph Bauer,** KWS Group (Germany)

Magnetostrictive particles used for biosensors for the detection of pathogen in liquid and their potential as a novel actuator *(Invited Paper)*, Kewei Zhang, Taiyuan Univ. of Science and Technology (China); ZhongYang Cheng, Auburn Univ. (USA) . . . . [9488-1]

High throughput pathogen screening for food safety using magnetoelastic biosensors *(Invited Paper)*, Suiqiong Li, Soochow Univ. (China); Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-2]

Detection of heavy metals with graphene-based biosensors, Nick Wu, West Virginia Univ. (USA) . . . . [9488-3]

In-situ detection of multiple pathogenic bacteria on food surfaces, Yating Chai, Shin Horikawa, Howard C. Wikle III, Auburn Univ. (USA); Jiajia Hu, Changzhou Univ. (China); Steve R. Best, Bryan A. Chin, Jing Dai, Auburn Univ. (USA) . . . . [9488-4]

Application of a LED-based reflectance sensor for the in situ assessment of lycopene content in tomatoes, Anna G. Mignani, Leonardo Ciaccheri, Andrea A. Mencaglia, Lorenza Tuccio, Giovanni Agati, Istituto di Fisica Applicata Nello Carrara (Italy) . . . . [9488-5]

Detection of salmonella of globe fruits using pulse excited magnetoelastic biosensors, Howard C. Wikle III, Songtao Du, Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-6]

SESSION 2 . . . . TUE 3:50 PM TO 5:30 PM

Sensing for Food Quality and Safety II

Session Chair: **Suiqiong Li,** Auburn Univ. (USA)

Bioenabled nanophotonic sensors for food safety and drinking water monitoring, Alan X. Wang, Jing Yang, Gregory L. Rorrer, Oregon State Univ. (USA) . . . . [9488-7]

Optimization of phage-based magnetoelastic biosensor to detect salmonella on bird feces contaminated leafy green vegetables, Jing Dai, Auburn Univ. (USA); Jiajia Hu, Changzhou Univ. (China); Yating Chai, Shin Horikawa, Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-8]

Electronic nose fabricated from nanocomposite oxides for agriculture applications, Dong-Joo Kim, Hyejin Park, Eunji Lee, Yoonsung Chung, Seok Hee Lee, Auburn Univ. (USA); Hosang Ahn, Korea Institute of Construction Technology (Korea, Republic of); Young Soo Yoon, Gachon Univ. (Korea, Republic of) . . . . [9488-9]

A biosensor based on magnetic resonance relaxation, MariAnne Sullivan, Barton C. Prorok, Auburn Univ. (USA) . . . . [9488-11]

Nature-inspired magnetoelastic biosentinels for the detection of pathogenic bacteria in stagnant liquids, Shin Horikawa, Yating Chai, Howard C. Wikle III, Jing Dai, Jiajia Hu, Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-12]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Detection of salmonella typhimurium in fecal contaminants on fresh produce using phase-based magnetoelastic biosensors, Jiajia Hu, Changzhou Univ. (China) and Auburn Univ. (USA); Jing Dai, Yating Chai, Shin Horikawa, Auburn Univ. (USA); Jing Hu, Changzhou Univ. (China); Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-10]

Rapid detection of foodborne pathogens in pork meat by surface-enhanced Raman scattering, Feifei Tao, Yankun Peng, China Agricultural Univ. (China) . . . . [9488-26]

Research on identification and determination of mixed pesticides in apples using surface enhanced Raman spectroscopy, Chen Zhai, Yankun Peng, Yongyu Li, Sagar Dhakal, Tianfeng Xu, China Agricultural Univ. (China) [9488-27]

Rapid detection of benzoyl peroxide added in wheat flour by using Raman scattering spectroscopy, Juan Zhao, Yankun Peng, China Agricultural Univ. (China); Kuanglin Chao, Jianwei Qin, Agricultural Research Service (USA); Sagar Dhakal, China Agricultural Univ. (China) . . . . [9488-28]

Nondestructive detection of pork quality based on dual-band VIS/NIR spectroscopy, Wenxiu Wang, Yankun Peng, Yuanyuan Liu, China Agricultural Univ. (China) . . . . [9488-29]

Depth of penetration of a 785nm wavelength laser in milk powder, Kuanglin Chao, Sagar Dhakal, Jianwei Qin, Moon S. Kim, Agricultural Research Service (USA); Yankun Peng, China Agricultural Univ. (China); Walter F. Schmidt, Agricultural Research Service (USA) . . . . [9488-30]

Rapid detection of salmonella typhimurium through improvements to magnetoelastic biosensors, Zhou Tong, Shin Horikawa, Bryan A. Chin, Auburn Univ. (USA); Laura A. Silo-Suh, Mercer Univ. (USA); Sang-Jin Suh, Auburn Univ. (USA) . . . . [9488-31]

Corrosion of magnetostrictive biosensors, Jiajia Hu, Changzhou Univ. (China) and Auburn Univ. (USA); Jing Hu, Changzhou Univ. (China); Yating Chai, Shin Horikawa, Bryan A. Chin, Auburn Univ. (USA) . . . . [9488-32]

Determination of the optimal analytical conditions for quickly detecting feces to cause contamination of potential pathogens in the field of agriculture using hyperspectral imaging, Hyunjeong Cho, Sungyoun Kim, Dongho Kim, Byuncheon Kim, Byunglim Cho, NAQS (Korea, Republic of) . . . . [9488-33]

Development of a quality monitoring method for Korean traditional rice wine 'makgeolli' using near-infrared spectroscopy, Dae Yong Kim, Kyungdo Kwon, Byoung-Kwan Cho, Chungnam National Univ. (Korea, Republic of) . . . . [9488-34]

Hyperspectral fluorescence imaging with violet LED excitation for monitoring drought stress effect on soybean plants, Changyeun Mo, National Academy of Agricultural Science (Korea, Republic of); Moon S. Kim, Agricultural Research Service (USA); Giyoung Kim, Jongguk Lim, National Academy of Agricultural Science (Korea, Republic of); Eunju Cheong, Jinyoung Barnaby, Agricultural Research Service (USA); Hyun-jeong Cho, NAQS (Korea, Republic of) . . . . [9488-35]

Multispectral imaging for browning detection of fresh-cut lettuce, Changyeun Mo, Giyoung Kim, Jongguk Lim, National Academy of Agricultural Science (Korea, Republic of); Byoung-Kwan Cho, Chungnam National Univ. (Korea, Republic of); Moon S. Kim, Agricultural Research Service (USA) . . . . [9488-36]

Hyperspectral imaging for contaminant detection in starch, Min Huang, Jiangnan Univ. (China) and Agricultural Research Service (USA); Moon S. Kim, Kuanglin Chao, Jianwei Qin, Agricultural Research Service (USA); Qibing Zhu, Jiangnan Univ. (China). . . . . [9488-37]

Production of an innovative fertilizer from organic waste: process monitoring by hyperspectral imaging, Silvia Serranti, Giuseppe Bonifazi, Andrea Fabbri, Univ. degli Studi di Roma La Sapienza (Italy); Alice Dall'Ara, ENEA (Italy); Carlos Garcia Izquierdo, CEBAS-CSIC (Spain) . . . . [9488-38]

Prediction of soluble solids content spatial distribution in apple using hyperspectral imaging and variable selection algorithms, Wenqian Huang, Liping Chen, Jiangbo Li, Zhiming Guo, National Research Ctr. of Intelligent Equipment for Agriculture (China) . . . . [9488-47]

WEDNESDAY 22 APRIL

SESSION 3 . . . . WED 8:40 AM TO 10:00 AM

Raman for Food Quality and Safety

Session Chair: **Kuanglin Chao,**
USDA gricultural Research Service (USA)

Second derivative analyses of temperature dependent Raman spectroscopy, Walter F. Schmidt, Leigh Broadhurst, Jianwei Qin, Kuanglin Chao, Daniel Shelton, Moon S. Kim, Agricultural Research Service (USA) . . . . [9488-13]

Dry mixture preparation by resonant acoustic mixing for Raman-spectroscopy-based contaminant detection, Sagar Dhakal, Kuanglin Chao, Jianwei Qin, Moon S. Kim, Agricultural Research Service (USA) . . . . . . [9488-14]

Screening of adulterants in powdered foods and ingredients using line-scan Raman chemical imaging, Jianwei Qin, Kuanglin Chao, Moon S. Kim, Agricultural Research Service (USA) . . . . [9488-15]

Shifted excitation Raman difference spectroscopy: a potential tool for outdoor measurements in precision agriculture, Martin Maiwald, André Müller, Ferdinand-Braun-Institut (Germany); Jörn Selbeck, Jana Käthner, Manuela Zude, Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V. (Germany); Dominique Fleury, Univ. of Applied Sciences at Changins (Switzerland); Bernd Sumpf, Götz Erbert, Günther Tränkle, Ferdinand-Braun-Institut (Germany) . . . . [9488-16]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 4 . . . . WED 1:20 PM TO 3:00 PM

Hyperspectral Imaging for Foods

Session Chairs: **Christoph Bauer,** KWS Group (Germany);
Seung-Chul Yoon, USDA Agricultural Research Service (USA)

Color-based hyperspectral imaging for safety inspection of poultry carcasses, Seung-Chul Yoon, Kurt C. Lawrence, Bosoon Park, Gary R. Gamble, Tae-Sung Shin, Gerald W. Heitschmidt, Agricultural Research Service (USA) . . . . [9488-17]

Chemometric analysis for near-infrared spectral detection of beef in fish meal, Chun-Chieh Yang, Agricultural Research Service (USA); Cristóbal Garrido-Novell, Dolores Pérez-Marín, José E. Guerrero-Ginel, Ana Garrido-Varo, Univ. de Córdoba (Spain); Moon S. Kim, Agricultural Research Service (USA) . . . . [9488-18]

Application of hyperspectral imaging and spectral similarity analysis for intramuscular fat quantification in beef, Santosh Lohumi, Sangdae Lee, Byoung-Kwan Cho, Chungnam National Univ. (Korea, Republic of) . . . [9488-19]

The use of short wave infrared hyperspectral imaging for discrimination of watermelon seed infestation by acidovorax citrulli, Hoonsoo Lee, Chungnam National Univ. (Korea, Republic of) . . . . [9488-20]

Spectroscopic techniques for examination of toxic metabolites in maize kernels, Lalit Mohan Kandpal, Hyun-Jung Min, Byoung-Kwan Cho, Chungnam National Univ. (Korea, Republic of) . . . . [9488-21]

SESSION 5 . . . . WED 3:30 PM TO 4:50 PM

Spectral Imaging for Foods

Session Chair: **Seung-Chul Yoon,**
USDA Agricultural Research Service (USA)

Classification of corn kernels inoculated with aspergillus flavus using fluorescence and reflectance visible near-infrared (VNIR) hyperspectral imaging, Fengle Zhu, Haibo Yao, Zuzana Hruska, Russell Kincaid, Mississippi State Univ. (USA); Robert L. Brown, Deepak Bhatnagar, Thomas E. Cleveland, U.S. Dept. of Agriculture (USA) . . . . [9488-22]

Discrimination of varieties of pear based on Vis/NIR spectroscopy and BP-ANN, Jiangbo Li, National Engineering Research Ctr. for Information Technology in Agriculture (China) . . . . [9488-23]

Using NOAA/AVHRR based remote sensing data and PCR method for estimation of Aus rice yield in Bangladesh, Mohammad Nizamuddin, The City College of New York (USA); Kawsar A. Akhand, The City Univ. of New York (USA); Leonid Roytman, The City College of New York (USA); Felix Kogan, Mitchell Goldberg, National Environmental Satellite, Data, and Information Service (USA). . . . . [9488-24]

Qualitative identification of green tea origin by near infrared spectroscopy and multivariatecalibration, Xingang Zhuang, Lili Wang, Jiaxiong Fang, Shandong Univ. (China); Xueyuan Wu, State Key Lab. of Tea and Agricultural Products Detection (China) . . . . [9488-25]

CONFERENCE 9489

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9489

Dimensional Optical Metrology and Inspection for Practical Applications IV

Conference Chairs: **Kevin G. Harding,** GE Global Research (USA); **Toru Yoshizawa,** NPO 3D Associates (Japan)

Conference Co-Chair: **Song Zhang,** Iowa State Univ. (USA)

Program Committee: **Yasuhiko Arai,** Kansai Univ. (Japan); **Anand Krishna Asundi,** Nanyang Technological Univ. (Singapore); **Khaled J. Habib,** Kuwait Institute for Scientific Research (Kuwait); **Katsuichi Kitagawa,** Consultant (Japan); **Peter Kühmstedt,** Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); **Georges T. Nehmetallah,** The Catholic Univ. of America (USA); **Yukitoshi Otani,** Utsunomiya Univ. (Japan); **Xianyu Su,** Sichuan Univ. (China); **Takamasa Suzuki,** Niigata Univ. (Japan); **Joseph D. Tobiason,** Micro Encoder Inc. (USA); **Jiangtao Xi,** Univ. of Wollongong (Australia)

MONDAY 20 APRIL

SESSION 1. . . . . MON 8:30 AM TO 10:00 AM

Metrology Analysis

Session Chair: **Toru Yoshizawa,** NPO 3D Associates (Japan)

3D range data compression with a virtual fringe projection system *(Invited Paper)*, Song Zhang, Iowa State Univ. (USA) . . . . [9489-1]

Phase unwrapping of fringe images for dynamic 3D measurements without additional pattern projection, Andreas Breitbarth, Eric Müller, Peter Kühmstedt, Gunther Notni, Fraunhofer-Institut für Angewandte Optik und Feinmechanik (Germany); Joachim Denzler, Friedrich-Schiller-Univ. Jena (Germany) . . . . [9489-2]

Experimental verification of reconstruction of two interfering wavefronts using the transport of intensity equation, Ahmad Darudi, Javad Amiri, Peyman Soltani, Univ. of Zanjan (Iran, Islamic Republic of); Georges T. Nehmetallah, The Catholic Univ. of America (USA). . . . . [9489-3]

Geometric and topological feature extraction of linear and circular segments from 2D cross-section data of 3D point clouds, Rajesh Ramamurthy, Yi Liao, Ratnadeep Paul, Kevin G. Harding, GE Global Research (USA) . . . . [9489-4]

SESSION 2 . . . . MON 10:30 AM TO 12:00 PM

3D Applications

Session Chair: **Song Zhang,** Iowa State Univ. (USA)

Inner profile measurement probe: from a pipe to an underground cavity *(Invited Paper)*, Toru Yoshizawa, NPO 3D Associates (Japan); Toshitaka Wakayama, Saitama Medical Univ. (Japan) . . . . [9489-5]

Development of feature extraction analysis for a multi-functional optical profiling device applied to field engineering applications, Kevin G. Harding, GE Global Research (USA); Xu Han, Guangping Xie, GE Global Research (China); Brandon Laflen, GE Global Research (USA); Ming Jia, GE Global Research (China) . . . . [9489-6]

Composite layup monitoring using structured light, Robert W. Tait, Kevin G. Harding, Christopher Nafis, GE Global Research (USA) . . . . . . [9489-7]

Characterization of 3D printing output using an optical sensing system, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9489-8]

Lunch Break . . . . .Mon 12:00 pm to 1:10 pm

SESSION 3 . . . . .MON 1:10 PM TO 2:10 PM

Metrology for Additive Manufacturing

Session Chair: **Edward W. Reutzel,** Applied Research Lab. (USA)

Sensors for modern manufacturing: certify as you build *(Invited Paper)*, Jyoti Mazumder, Lijun Song, Univ. of Michigan (USA) . . . . [9489-9]

A brief survey of sensing for additive manufacturing *(Invited Paper)*, Edward W. Reutzel, Abdalla R. Nassar, Applied Research Lab. (USA). . [9489-10]

PANEL DISCUSSION. . . . . 2:10 PM TO 3:30 PM

Metrology for Additive Manufacturing

Moderator: **Edward W. (Ted) Reutzel,** Applied Research Lab. (USA)

Panelists: **Doug Rhoda,** Wolf Robotics (USA);
Radovan Kovacevic, Southern Methodist Univ. (USA);
Shawn Kelly, Edison Welding Institute (USA);
Jyoti Mazumder, Univ. of Michigan (USA);
Edward Herderick, GE Corporate (USA)

Process sensing plays an increasingly important role in a wide range of manufacturing processes, both to enable rapid assessment of quality and to provide critical data to real time control systems. Advanced sensors and exploding computational capability afford (i) practitioners, (ii) equipment suppliers, and (iii) researchers unprecedented opportunities to collect and analyze complex sensor data to ensure quality product.

This panel discussion brings together leaders representing these three communities to discuss sensing and control for laser, electron beam, and arc-based welding, metal deposition, and additive manufacturing processes. The current state-of-the-art, current research, issues, and opportunities will be explored.

SESSION 4 . . . . MON 4:00 PM TO 5:00 PM

Advanced Topics

Session Chair: **Yukitoshi Otani,** Utsunomiya Univ. (Japan)

Thickness and air gap measurement of assembled IR objectives, Bernd Lueerss, Patrik Langehanenberg, TRIOPTICS GmbH (Germany). . . . . . [9489-11]

Method for controlling a laser additive process using intrinsic illumination, Guoshuang Cai, Robert W. Tait, Sudhir Tewari, Magdi N. Azer, Xiaobin Chen, David Abbot, Yong Liu, Kevin G. Harding, GE Global Research (USA) . [9489-12]

The impact of oceanic gravity waves on laser propagation, Serdar Kizilkaya, Cumhuriyet Mah. (Turkey); Timothy Kane, The Pennsylvania State Univ. (USA) . . . . [9489-13]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 5 . . . . TUE 8:30 AM TO 12:10 PM

3D and Imaging Methods

Session Chair: **Kevin G. Harding,** GE Global Research (USA)

Measuring accuracy of in-plane and out-of-plane deformations simultaneous measurement of speckle interferometry using multi-recording method *(Invited Paper)*, Yasuhiko Arai, Kansai Univ. (Japan). . . . . [9489-14]

Long wave infrared 3D scanner, Ernst Wiedenmann, Robert Schott, Jan Tusch, Andreas Wolf, Aimess Services GmbH (Germany). . . . . [9489-15]

Terahertz reflection interferometry for automobile paint layer thickness measurement, Aunik K. Rahman, Applied Research & Photonics, Inc. (USA); Kenneth B. Tator, KTA-Tator, Inc. (USA); Anis Rahman, Applied Research & Photonics, Inc. (USA) . . . . [9489-16]

Quantitative imaging of open-circuit voltage in opto-electronic devices with nanoscale resolution, Elizabeth Tennyson, Joseph Garrett, Univ. of Maryland, College Park (USA); Jesse A. Frantz, Jason D. Myers, Robel Y. Bekele, U.S. Naval Research Lab. (USA); Jasbinder S. Sanghera, Univ. Research Foundation (USA) and U.S. Naval Research Lab. (USA); Jeremy N. Munday, Marina S. Leite, Univ. of Maryland, College Park (USA) . . . . [9489-17]

Application of holographic interferometry to in-plane and out-of-plane misalignment and deformation measurements in packaging applications, Vladimir V. Nikulin, Rahul M. Khandekar, Vijit Bedi, Binghamton Univ. (USA) . . . . [9489-18]

Real-time and uniaxial microscopic measurement of 3D profile by polarization grating, Yukitoshi Otani, Shuhei Shibata, Daisuke Barada, Utsunomiya Univ. (Japan) . . . . [9489-19]

3D position tracking for borescope inspections, Kevin G. Harding, GE Global Research (USA); Yong Yang, GE Global Research (China); Guiju Song, GE Global Research (USA) . . . . [9489-20]

Small hole inner profile measurement method, Yi Liao, Kevin G. Harding, Rajesh Ramamurthy, GE Global Research (USA) . . . . [9489-21]

High contrast imaging in the presence of a bright background, Harbans S. Dhadwal, Jahangir Rastegar, Dake Feng, Omnitek Partners, LLC (USA) . . . . [9489-22]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

The omni-directional image assisted optical surveillance system, Yung-Hsiang Chen, National Applied Research Labs. (Taiwan) and National Tsing Hua Univ. (Taiwan); Chi-Hung Hwang, National Applied Research Labs. (Taiwan); Wei-Chung Wang, National Tsing Hua Univ. (Taiwan); Chun-Fu Lin, National Applied Research Labs. (Taiwan) . . . . [9489-23]

CONFERENCE 9490

Monday 20 April 2015 • Proceedings of SPIE Vol. 9490

Advances in Global Health through Sensing Technologies 2015

Conference Chair: **Šárka O. Southern,** Gaia Medical Institute (USA)

Conference Co-Chairs: **Isaac R. Rodriguez-Chavez,** National Institute of Dental and Craniofacial Research (USA); **Claudia Gärtner,** microfluidic ChipShop GmbH (Germany); **Jonathan D. Stallings,** U.S. Army Ctr. for Environmental Health Research (USA)

Program Committee: **James Delehanty,** U.S. Naval Research Lab. (USA); **Theresa G. Evans-Nguyen,** Draper Lab. (USA); **Peter Kiesel,** Palo Alto Research Ctr., Inc. (USA); **Baochuan Lin,** U.S. Naval Research Lab. (USA); **Daniel Malamud,** New York Univ. (USA); **Igor Medintz,** U.S. Naval Research Lab. (USA); **Richard M. Ozanich,** Pacific Northwest National Lab. (USA); **Ava M. Puccio,** Univ. of Pittsburgh Medical Ctr. (USA); **Steven A. Ripp,** The Univ. of Tennessee (USA); **Albert Skip Rizzo III,** The Univ. of Southern California (USA); **Kim E. Sapsford,** U.S. Food and Drug Administration (USA); **Shadrian B. Strong,** Johns Hopkins Univ. Applied Physics Lab. (USA); **David E. Wolf,** Radiation Monitoring Devices, Inc. (USA); **Aurel Ymeti,** Ostendum R&D BV (Netherlands); **Leah Ziph-Schatzberg,** Corning NetOptix (USA)

MONDAY 20 APRIL

SESSION 1. . . . . MON 8:00 AM TO 10:30 AM

Advances in Global Health I

Session Chairs: **Isaac R. Rodriguez-Chavez,** National Institute of Dental and Craniofacial Research (USA); **Šarka O. Southern,** Gaia Medical Institute (USA)

Non-invasive disease diagnostics based on oral biospecimens: lessons learned and future directions *(Invited Paper)*, Isaac R. Rodriguez-Chavez, National Institute of Dental and Craniofacial Research (USA). . . . . [9490-1]

The human saliva proteome: overview and emerging methods for characterization *(Invited Paper)*, Timothy J. Griffin, Univ. of Minnesota (USA) . . . . [9490-2]

Comparison between oral and salivary diagnostics *(Invited Paper)*, J. Marques, Univ. de Lisbon (Portugal); Patricia Corby, C. Barber, William R. Abrams, New York Univ. College of Dentistry (USA); Daniel Malamud, New York Univ. (USA) . . . . [9490-3]

Saliva fluid considerations in oral diagnostics, Eva J. Helmerhorst, Boston Univ. (USA) . . . . [9490-4]

Addressing the challenges of system integration for non-invasive diagnostics, Vincent Gau, Genefluidics (USA). . . . . [9490-5]

Saliva-based molecular diagnostics of HPV, Jennifer Webster-Cyriaque, The Univ. of North Carolina at Chapel Hill (USA); William Seaman, Univ. of North Carolina at Chapel Hill (USA). . . . . [9490-6]

Next Generation saliva diagnostics: host response biomarkers for HIV diagnostics,Šarka O. Southern, Gaia Medical Institute (USA); Jennifer Webster-Cyriaque, The Univ. of North Carolina at Chapel Hill (USA); Martin Gleeson, Genalyte, Inc. (USA) . . . . [9490-7]

SESSION 2 . . . . MON 10:45 AM TO 12:30 PM

Advances in Global Health II

Session Chairs: **Jonathan D. Stallings,** U.S. Army Ctr. for Environmental Health Research (USA); **Utkan Demirci,** Stanford Univ. School of Medicine (USA)

Early predictive markers of organ injury and toxicity *(Invited Paper)*, Danielle L. Ippolito, U.S. Army Ctr. for Environmental Health Research (USA); Mohamed D. M. AbdulHameed, Gregory J. Tawa, BHSAI (USA); John A. Lewis, U.S. Army Ctr. for Environmental Health Research (USA); Christine E. Baer, EXCET, Inc. (USA); Bonna C. Donald, Oak Ridge Institute for Science and Education (USA); Anders Wallqvist, BHSAI (USA); Jonathan D. Stallings, U.S. Army Ctr. for Environmental Health Research (USA) . . . . [9490-8]

Detecting biotargets and drugs from blood, urine and saliva *(Invited Paper)*, Utkan Demirci, Stanford Univ. School of Medicine (USA). . . . . [9490-9]

Imaging-based rapid test and assay reader with trans-visual sensitivity, Onur Mudanyali, Neven Karlovac, Holomic (USA) . . . . [9490-10]

Multiplex on-chip detection of pathogen biomarkers in human saliva using silicon photonic microring resonators, Martin A. Gleeson, Genalyte, Inc. (USA) . . . . [9490-11]

Optical biosensor technologies for molecular diagnostics at the point-of-care, Joerg M. Schotter, Stefan Schrittwieser, Paul Muellner, Eva Melnik, Rainer Hainberger, AIT Austrian Institute of Technology GmbH (Austria); Guenther Koppitsch, Franz Schrank, ams AG (Austria); Katerina Soulantika, Sergio Lentijo-Mozo, Institut National des Sciences Appliquées de Toulouse (France) and Lab. de Photonique et de Nanostructures, CNRS, Univ. de Toulouse (France); Beatriz Pelaz, Wolfgang J. Parak, Philipps-Univ. Marburg (Germany); Frank Ludwig, Jan Dieckhoff, Technische Univ. Braunschweig (Germany) . . . . [9490-12]

Lunch Break . . . . .Mon 12:30 pm to 1:30 pm

SESSION 3 . . . . MON 1:30 PM TO 5:00 PM

Advances in Global Health III

Session Chairs: **Claudia Gärtner,** microfluidic ChipShop GmbH (Germany); **Amy E. Herr,** Univ. of California, Berkeley (USA)

Microfluidic design for next-generation diagnostics *(Invited Paper)*, Amy E. Herr, Univ. of California, Berkeley (USA) . . . . [9490-13]

Lab-on-a-chip enabled HLA diagnostic: combined sample preparation and real time PCR for HLA-b27 diagnosis *(Invited Paper)*, Claudia Gärtner, Holger Becker, Richard Klemm, Sebastian Schattschneider, Nadine Hlawatsch, Christian Moche, microfluidic ChipShop GmbH (Germany); Rainer Frank, Andreas Willems, Inno-Train Diagnostik GmbH (Germany) . . . . [9490-14]

Microchip technologies for HIV management in developed and developing countries, Hadi Shafiee, Brigham and Women's Hospital (USA). . . . . . [9490-15]

Rapid detection of ebola virus in immunofiltration lab on chip system, Peter Miethe, fzmb GmbH (Germany); Claudia Gärtner, microfluidic ChipShop GmbH (Germany); Dominik Gary, fzmb GmbH (Germany); Nadine Hlawatsch, microfluidic ChipShop GmbH (Germany) . . . . [9490-16]

Low cost molecular diagnostics for cancer and infectious disease, Catherine Klapperich, Boston Univ. (USA) . . . . [9490-17]

PANDAA: rapid, sensitive detection of highly polymorphic pathogens and quantification of drug resistance, Iain J. MacLeod, Harvard School of Public Health (USA) and Botswana-Harvard AIDS Institute (Botswana) and Aldatu Biosciences (USA); Christopher F. Rowley, Harvard School of Public Health (USA) and Botswana-Harvard AIDS Institute (Botswana) and Beth Israel Deaconess Medical Ctr. (USA); David M. Raiser, Aldatu Biosciences (USA); M. Essex, Harvard School of Public Health (USA) and Botswana-Harvard AIDS Institute (Botswana). . . . . [9490-18]

Next generation DNA, Steven Albert Benner, The Westheimer Institute for Science and Technology (USA). . . . . [9490-19]

Developing targeted immunotherapies and vaccines against difficult to treat infectious diseases, Frank Jones, Elizabeth Gabitzsch, Etubics Corp. (USA) . . . . [9490-20]

Nanopore sensing technology for single molecule and single cell analysis, MinJun Kim, Drexel Univ. (USA) . . . . [9490-21]

Homogeneous biochemiluminescence assays for point of care use, X. James Li, Cellex, Inc. (USA) . . . . [9490-22]

Advances in global health through sensing technologies, Jonathan C. Claussen, Iowa State Univ. (USA) . . . . [9490-23]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Differential excitation spectroscopy for detection of industrial chemicals: benzene and chlorinated solvents, Boyd V. Hunter, Jason M. Cox, Kestrel Corp. (USA); Michael A. Miller, Robert A. McIntosh, Southwest Research Institute (USA); Paul Harrison, William P. Walters, Kestrel Corp. (USA) . [9490-24]

Advancing innovative regulatory science and public health through CDx: FDA's development of a counterfeit detection tool, Leigh Verbois, U.S. Food and Drug Administration (USA) . . . . [9490-25]

Sensors for isolation of anti-cancer compounds found within marine invertebrates, Gordon W. Wiegand, Amanda C. LaRue, Medical Univ. of South Carolina (USA) . . . . [9490-26]

Space medical applications of optical 3D scanning, Jeremy Straub, Univ. of North Dakota (USA); Atif F. Mohammad, The Univ. of North Dakota (USA) . . . . [9490-27]

Early detection and monitoring of malaria, Mohammed Z. Rahman, LaGuardia Community College (USA); Leonid Roytman, The City College of New York (USA); Abdelhamid Kadik, Howard Miller, LaGuardia Community College (USA); Dilara A. Rosy, Univ. of Dhaka (Bangladesh) . . . . [9490-28]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9491

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9491

Sensors for Extreme Harsh Environments II

Conference Chairs: **Debbie G. Senesky,** Stanford Univ. (USA); **Sachin Dekate,** GE Global Research (USA)

Program Committee: **Laurent A. Francis,** Univ. Catholique de Louvain (Belgium); **Jr-Hau (J.H.) He,** King Abdullah Univ. of Science and Technology (Saudi Arabia); **Kevin S. C. Kuang,** National Univ. of Singapore (Singapore)

WEDNESDAY 22 APRIL

SESSION 1. . . . . WED 3:30 PM TO 5:40 PM

Novel Harsh Environment Sensors for Energy Applications

Joint Session with Conferences 9467 and 9491

Session Chair: **Michael P. Buric,** National Energy Technology Lab. (USA)

Functional sensor material enabled harsh environment, high temperature optical sensors for energy applications *(Keynote Presentation)*, Paul R. Ohodnicki Jr., National Energy Technology Lab. (USA) . . . . [9467-53]

Ultra-high temperature fiber optical chemical sensors based on nano-porous metal oxides *(Invited Paper)*, Kevin P. Chen, Univ. of Pittsburgh (USA) . . . . [9467-54]

Phosphor-based fiber optic temperature sensors for harsh environments *(Invited Paper)*, Nicholas Djeu, Yutaka Shimoji, MicroMaterials, Inc. (USA) . . . . [9467-55]

Development of Laser induced breakdown spectroscopy (LIBS) sensor to assess groundwater quality impacts *(Invited Paper)*, Dustin McIntyre, Jinesh Jain, Cantwell Carson, Christian Goueguel, National Energy Technology Lab. (USA) . . . . [9467-56]

Temperature dependence of hydrogen related absorption in silica glass optical fibers at high temperatures *(Invited Paper)*, Elizabeth A. Bonnell, Li Yu, Daniel Homa, Virginia Tech Ctr. for Photonics Technology (USA) . . . . . [9467-57]

Analysis of the coupling optical fiber ultrasonic sensor for partial discharges detection, Fengmei F. Li, Yiying Liu, Linjie Wang, Chen Yu, Xi'an Jiaotong Univ. (China) . . . . [9491-15]

THURSDAY 23 APRIL

SESSION 2 . . . . .THU 8:00 AM TO 10:20 AM

Micro/Nano Sensing Technology for Harsh Environments

Session Chair: **Debbie G. Senesky,** Stanford Univ. (USA)

Harsh environment compatible chemical sensors: plasmonics and electrochemical device principles, Michael A. Carpenter, SUNY College of Nanoscale Science and Engineering (USA). . . . . [9491-1]

Growth and morphology of lead tin selenide for MWIR detectors, Christopher Cooper, Univ. of Maryland, Baltimore County (USA); Narasimha S. Prasad, NASA Langley Research Ctr. (USA); Bradley Arnold, Lisa Kelly, Fow-Sen Choa, Narsingh B. Singh, Univ. of Maryland, Baltimore County (USA) . . . . [9491-2]

Atomic layer deposited passivation films for AlGaN/GaN high electron mobility radiation dosimeters, Ateeq J. Suria, Stanford Univ. (USA); Chetan Angadi, Sharmila Bhattacharya, NASA Ames Research Ctr. (USA); Debbie G. Senesky, Stanford Univ. (USA) . . . . [9491-3]

Solar cells for harsh environments uses based on InGaN/GaN multiple quantum wells, Der-Hsien Lien, Yu-Hsuan Hsiao, Shih-Guo Yang, Si-Chen Lee, National Taiwan Univ. (Taiwan); Jr-Hau He, King Abdullah Univ. of Science and Technology (Saudi Arabia) . . . . [9491-4]

Irradiation effects of graphene-enhanced gallium nitride (GaN) metal-semiconductor-metal (MSM) ultraviolet photodetectors, Heather C. Chiamori, Nicholas Broad, Ruth Miller, Debbie G. Senesky, Stanford Univ. (USA) . . . . [9491-5]

Investigation of the optical and sensing characteristics of nanoparticle arrays for high temperature applications, Gnanaprakash Dharmalingam, Michael A. Carpenter, SUNY College of Nanoscale Science and Engineering (USA) . . . . [9491-6]

Wireless photonic power and data transfer to dormant devices, Harbans S. Dhadwal, Jahangir Rastegar, Dake Feng, Philip Kwok, Omnitek Partners, LLC (USA) . . . . [9491-7]

SESSION 3 . . . . THU 11:00 AM TO 12:00 PM

Optical Sensing Technology for Harsh Environments I

Session Chair: **Sachin Dekate,** GE Global Research (USA)

Characterization and calibration of Raman based distributed temperature sensing system for 600C operation, Sudeep Mandal, Boon Kwee Lee, Sachin Dekate, Renato Guida, GE Global Research (USA); Marc Goranson, Jerome Ybema, Suncor Energy Products, Ltd. (Canada) . . . . [9491-8]

Coherent probe-pump-based Brillouin sensor for harsh environments, L. F. Zou, OZ Optics Ltd. (Canada) . . . . [9491-9]

Potential of commercial single-mode optical fibers as distributed sensors for high temperature measurement with PPP-BOTDA, Yi Bao, Yizheng Chen, Fujian Tang, Weina Meng, Genda Chen, Missouri Univ. of Science and Technology (USA) . . . . [9491-10]

Lunch Break and Exhibition Time . . . . Thu 12:00 pm to 1:30 pm

SESSION 4 . . . . THU 1:30 PM TO 3:10 PM

Optical Sensing Technology for Harsh Environments II

Session Chair: **Sachin Dekate,** GE Global Research (USA)

Optical sensors for harsh environment applications, Rachit Sharma, GE Global Research (India); Anish Bekal, Arun K. Sridharan, Sameer Vartak, Chayan Mitra, GE India Technology Centre Pvt. Ltd. (India) . . . . [9491-11]

Analysis of the acoustic response in water and sand of different fiber optic sensing cables, Joachim Hofmann, Brugg Kabel AG (Switzerland) . . . [9491-12]

Optical fiber distributed temperature and distributed acoustic sensing for remote and harsh environments, Michael Mondanos, Tom Parker, Craig Milne, Jackson Yeo, Silixa Ltd. (United Kingdom); Mahmoud Farhadiroushan, Silixa, Ltd. (United Kingdom). . . . . [9491-13]

Planetary atmospheres minor species sensor balloon flight test to near space, Robert E. Peale, Christopher J. Fredricksen, Andrei V. Muraviev, Douglas Maukonen, Seth Calhoun, Joshua E. Colwell, Univ. of Central Florida (USA) . . . . [9491-14]

Optical fiber reliability in subsea monitoring, Kaustubh Nagarkar, Victor Ostroverkhov, Thomas Stecher, Mahadevan Balasubramaniam, Glen Koste, Sachin Dekate, Slawomir Rubinsztajn, GE Global Research (USA) . . . . [9491-16]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

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Thermal stability and energy harvesting characteristics of Au nanorods: harsh environment chemical sensing, Nicholas A. Karker, Gnanaprakash Dharmalingam, Nicholas Joy, Michael A. Carpenter, SUNY College of Nanoscale Science and Engineering (USA). . . . . [9491-17]

Microfabricated electrochemical sensors for combustion applications, Vitor A. Vulcano Rossi, SUNY College of Nanoscale Science and Engineering (USA); Max Mullen, The Ohio State Univ. (USA); Nicholas A. Karker, Zhouying Zhao, SUNY College of Nanoscale Science and Engineering (USA); Marek Kowarz, Smart System Technology & Commercialization Ctr. (USA); Prabir K. Dutta, The Ohio State Univ. (USA); Michael A. Carpenter, SUNY College of Nanoscale Science and Engineering (USA). . . . . [9491-18]

Data communication through multiple physical media: applications to munitions, Harbans S. Dhadwal, Jahangir Rastegar, Dake Feng, Philip Kwok, Omnitek Partners, LLC (USA) . . . . [9491-19]

Lessons learned and experience from land collapse accidents using remote sensing and GIS: case study of continuous land collapse in east Cairo area, Egypt, Mohamed N. Hegazy, National Authority for Remote Sensing and Space Sciences (Egypt) . . . . [9491-20]

CONFERENCE 9492

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9492

Advanced Photon Counting Techniques IX

Conference Chair: **Mark A. Itzler,** Princeton Lightwave, Inc. (USA)

Conference Co-Chair: **Joe C. Campbell,** Univ. of Virginia (USA)

Program Committee: **Gerald S. Buller,** Heriot-Watt Univ. (United Kingdom); **Sergio Cova,** Politecnico di Milano (Italy); **William H. Farr,** Jet Propulsion Lab. (USA); **Robert H. Hadfield,** Univ. of Glasgow (United Kingdom); **Majeed Hayat,** The Univ. of New Mexico (USA); **Michael A. Krainak,** NASA Goddard Space Flight Ctr. (USA); **Robert A. Lamb,** SELEX Galileo Ltd. (United Kingdom); **K. Alex McIntosh,** MIT Lincoln Lab. (USA); **Alan L. Migdall,** National Institute of Standards and Technology (USA); **Michael Wahl,** PicoQuant GmbH (Germany); **Hugo Zbinden,** Univ. of Geneva (Switzerland)

WEDNESDAY 22 APRIL

SESSION 1. . . . . WED 8:20 AM TO 10:00 AM

Single-Photon Applications I

Session Chair: **Joe C. Campbell,** Univ. of Virginia (USA)

Cutting the cord: toward wireless optical intensity interferometry *(Invited Paper)*, Elliott P. Horch, Southern Connecticut State Univ. (USA) . . . . . . [9492-1]

Time and spectrum-resolving multiphoton correlator for 300-900 nm, Piotr L. Kolenderski, Nicolaus Copernicus Univ. (Poland); Kelsey Johnsen, Institute for Quantum Computing (Canada); Thomas D. Jennewein, Univ. of Waterloo (Canada); Marilyne Thibault, Institute for Quantum Computing (Canada); Alberto Tosi, Carmelo Scarcella, Politecnico di Milano (Italy) . . . . [9492-2]

Photon counting camera for fluorescence lifetime imaging *(Invited Paper)*, Werner Zuschratter, Yury Prokazov, Evgeny Turbin, André Weber, Leibniz Institute für Neurobiologie Magdeburg (Germany); Roland Hartig, Otto-von-Guericke Univ. Magdeburg (Germany) . . . . [9492-3]

48-confocal-spots single-molecule measurements using a custom 48-pixel SPAD arrays with integrated timestamping, Antonino Ingargiola, Univ. of California, Los Angeles (USA); Luca Miari, Ivan Rech, Angelo Gulinatti, Massimo Ghioni, Politecnico di Milano (Italy); Shimon Weiss, Xavier Michalet, Univ. of California, Los Angeles (USA) . . . . [9492-4]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 2. . . . . WED 1:00 PM TO 1:45 PM

Keynote: SPDs and Quantum Sensing

Session Chair: **Mark A. Itzler,** Princeton Lightwave, Inc. (USA)

Single photon detectors and quantum sensing *(Keynote Presentation)*, John G. Rarity, Univ. of Bristol (United Kingdom) . . . . [9492-5]

SESSION 3 . . . . WED 1:45 PM TO 3:05 PM

Single-Photon Applications II

Session Chair: **Mark A. Itzler,** Princeton Lightwave, Inc. (USA)

Quantum key distribution on lit fibre *(Invited Paper)*, Zhiliang L. Yuan, Toshiba Research Europe Ltd. (United Kingdom). . . . . [9492-6]

Photon-counting communications receiver in the lunar lasercom ground terminal *(Invited Paper)*, Matthew E. Grein, Eric A. Dauler, Andrew J. Kerman, Mark L. Stevens, Richard J. Molnar, Bryan S. Robinson, Daniel V. Murphy, Don M. Boroson, MIT Lincoln Lab. (USA). . . . . [9492-7]

Single photon counting for space based quantum experiments, Rakhitha Chandrasekara, Zhongkan Tang, Yue Chuan Tan, Yong Sean Yau, Cliff Cheng, Ctr. for Quantum Technologies (Singapore); Christoph F. Wildfeuer, Kantonsschule Sursee (Switzerland); Alexander Ling, National Univ. of Singapore (Singapore). . . . . [9492-8]

SESSION 4 . . . . WED 3:35 PM TO 5:55 PM

Superconducting Single-Photon Detectors

Session Chair: **William H. Farr,** Jet Propulsion Lab. (USA)

Real-time, infrared single-photon imaging with a superconducting nanowire camera *(Invited Paper)*, Martin J. Stevens, Michael S. Allman, Varun B. Verma, Robert D. Horansky, National Institute of Standards and Technology (USA); Francesco Marsili, Matthew D. Shaw, Andrew D. Beyer, Jet Propulsion Lab. (USA); Richard P. Mirin, Sae Woo Nam, National Institute of Standards and Technology (USA). . . . . [9492-9]

Single photon imaging with superconducting nanowire single photon detectors *(Invited Paper)*, Robert H. Hadfield, Univ. of Glasgow (United Kingdom). . . . . [9492-10]

High performance superconducting nanowire single photon detectors embedded in silicon nanobeam cavities *(Invited Paper)*, Mohsen K. Akhlaghi, Ellen Schelew, Jeff F. Young, The Univ. of British Columbia (Canada) . [9492-11]

Waveguide-integrated WSi-based superconducting nanowire single-photon detectors *(Invited Paper)*, Ryan M. Briggs, Matthew D. Shaw, Francesco Marsili, Andrew D. Beyer, Jet Propulsion Lab. (USA); Justin D. Cohen, Sean Meenehan, Oskar J. Painter, California Institute of Technology (USA) . . . . [9492-12]

Large-area NbN superconducting nanowire avalanche photon detectors with saturated detection efficiency, Ryan P. Murphy, Matthew E. Grein, Theodore J. Gudmundsen, MIT Lincoln Lab. (USA); Adam McCaughan, Faraz Najafi, Massachusetts Institute of Technology (USA); Francesco Marsili, Jet Propulsion Lab. (USA); Eric A. Dauler, MIT Lincoln Lab. (USA) . . . . [9492-13]

THURSDAY 23 APRIL

SESSION 5 . . . . THU 8:10 AM TO 10:00 AM

Single-Photon LIDAR I

Session Chair: **Michael A. Krainak,**
NASA Goddard Space Flight Ctr. (USA)

Multi-channel single photon receiver for IceSat-2 Mission ATLAS instrument *(Invited Paper)*, Guangning Yang, Michael A. Krainak, Xiaoli Sun, NASA Goddard Space Flight Ctr. (USA); Wei Lu, As and D, Inc. (USA); William E. Hasselbrack, Sigma Space Corp. (USA) . . . . [9492-14]

Photon counting using maximal length sequences: a theoretical assessment of pseudo-random coding for rangefinding *(Invited Paper)*, Robert A. Lamb, SELEX ES (United Kingdom) . . . . [9492-15]

Time-of-flight laser ranging for moving targets with single-photon counting *(Invited Paper)*, Yan Liang, Univ. of Shanghai for Science and Technology (China); Heping Zeng, Univ. of Shanghai for Science and Technology (China) and East China Normal Univ. (China) . . . . [9492-16]

Underwater depth imaging using time-correlated single photon counting, Aurora Maccarone, Aongus McCarthy, Ximing Ren, Andrew M. Wallace, Heriot-Watt Univ. (United Kingdom); James Moffat, Defence Science and Technology Lab. (United Kingdom); Yvan R. Petillot, Gerald S. Buller, Heriot-Watt Univ. (United Kingdom). . . . . [9492-17]

SESSION 6 . . . . THU 10:30 AM TO 11:40 AM

Single-Photon LIDAR II

Session Chair: **Robert A. Lamb,** SELEX Galileo Ltd. (United Kingdom)

Real-time imaging and tracking of objects hidden from view using SPAD imaging arrays *(Invited Paper)*, Daniele Faccio, Genevieve Gariepy, Francesco Tonolini, Heriot-Watt Univ. (United Kingdom); Nikola Krstajic, Robert K. Henderson, The Univ. of Edinburgh (United Kingdom); Jonathan Leach, Heriot-Watt Univ. (United Kingdom) . . . . [9492-18]

Study of single photon counting for non line of sight vision, Martin Laurenzis, Institut Franco-Allemand de Recherches de Saint-Louis (France); Jonathan Klein, Univ. Bonn (Germany); Andreas Velten, Univ. of Wisconsin-Madison (USA) and Morgridge Institute for Research (USA); Matthias B. Hullin, Univ. Bonn (Germany); Frank Christnacher, Institut Franco-Allemand de Recherches de Saint-Louis (France) . . . . [9492-19]

Hybrid receiver system for single photon sensitive direct and coherent detection, Piotr K. Kondratko, Paul J. Suni, Andrew T. Bratcher, John J. Glennon III, Lockheed Martin Coherent Technologies (USA) . . . . [9492-20]

Lunch Break and Exhibition Time . . . . Thu 11:40 am to 12:50 pm

SESSION 7 . . . . THU 12:50 PM TO 3:20 PM

Geiger-Mode APDs

Session Chair: **K. Alex McIntosh,** MIT Lincoln Lab. (USA)

Silicon Geiger-mode avalanche photodiode arrays for photon-starved imaging *(Invited Paper)*, Brian F. Aull, MIT Lincoln Lab. (USA). . . . . [9492-21]

Gun muzzle flash detection using a single photon avalanche diode array in 0.18µm CMOS technology *(Invited Paper)*, Vitali Savuskan, Tomer Merhav, Avi Shoham, Igor Brouk, Yael Nemirovsky, Technion-Israel Institute of Technology (Israel) . . . . [9492-22]

Analysis and modeling of optical crosstalk in InP-based Geiger-mode avalanche photodiode FPAs, Quan Chau, Xudong Jiang, Mark A. Itzler, Mark Entwitsle, Mark Owens, Krystyna Slomkowski, Princeton Lightwave, Inc. (USA) . . . . [9492-23]

Model of turn-on characteristics of InP-based Geiger–mode avalanche photodiodes suitable for circuit simulations, George Jordy, Joseph P. Donnelly, MIT Lincoln Lab. (USA) . . . . [9492-24]

Low noise InGaAs/inp single-photon negative feedback avalanche diodes: characterization and applications *(Invited Paper)*, Gianluca Boso, Boris Korzh, Tommaso Lunghi, Hugo Zbinden, Univ. de Genève (Switzerland) . . . . . [9492-25]

Al0.8Ga0.2As avalanche photodiodes for single photon counting, Min Ren, Yaojia Chen, Wenlu Sun, Joe C. Campbell, Univ. of Virginia (USA); Xiao Jie Chen, Erik B. Johnson, James F. Christian, Radiation Monitoring Devices, Inc. (USA) . . . . [9492-26]

SESSION 8 . . . . THU 3:50 PM TO 5:40 PM

Novel Avalanche Diode SPDs

Session Chair: **Alan L. Migdall,**
National Institute of Standards and Technology (USA)

Nanopillar optical antenna avalanche detectors: 3D nanoscale electric fields for high speed, low noise avalanche gain *(Invited Paper)*, Pradeep N. Senanayake, Alan Farrell, Diana L. Huffaker, Univ. of California, Los Angeles (USA) . . . . [9492-27]

Visible to infrared photon counting with the MWIR HgCdTe e-APD *(Invited Paper)*, William W. Sullivan III, Jeffrey D. Beck, Richard Scritchfield, Mark R. Skokan, Pradip Mitra, DRS Technologies, Inc. (USA); Xiaoli Sun, James B. Abshire, NASA Goddard Space Flight Ctr. (USA); Darren P. Carpenter, Barry L. Lane, Analog/Digital Integrated Circuits, Inc. (USA) . . . . [9492-28]

Recent progress in upconversion detector and its application *(Invited Paper)*, Qiang Zhang, Univ. of Science and Technology of China (China) . . . . [9492-29]

Phase preservation and ultra-low background in parametric up-conversion at the single-photon level, Yu-Hsiang Cheng, Tim O. Thomay, Joint Quantum Institute (USA) and National Institute of Standards and Technology (USA); Alan L. Migdall, Glenn S. Solomon, Joint Quantum Institute (USA) and National Institute of Standards and Technology (USA); Sergey V. Polyakov, Joint Quantum Institute (USA) and National Institute of Standards and Technology (USA) . . . . [9492-30]

CONFERENCE 9493

Tuesday 21 April 2015 • Proceedings of SPIE Vol. 9493

Energy Harvesting and Storage: Materials, Devices, and Applications VI

Conference Chairs: **Nibir K. Dhar,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Achyut K. Dutta,** Banpil Photonics, Inc. (USA)

Program Committee: **Pulickel M. Ajayan,** Rice Univ. (USA); **Paul Boieriu,** EPISOLAR, Inc. (USA); **Deryn Chu,** U.S. Army Research Lab. (USA); **M. Saif Islam,** Univ. of California, Davis (USA); **Nobuhiko P. Kobayashi,** Univ. of California, Santa Cruz (USA); **Pooi See Lee,** Nanyang Technological Univ. (Singapore); **Pat McGrath,** Booz Allen Hamilton Inc. (USA); **Robert Olah,** Banpil Photonics, Inc. (USA); **Kimberly A. Sablon,** U.S. Army Research Lab. (USA); **A. Fred Semendy,** U.S. Army Research Lab. (USA); **Sivalingam Sivananthan,** EPIR Technologies (USA); **Ashok K. Sood,** Magnolia Optical Technologies, Inc. (USA); **Patrick J. Taylor,** U.S. Army Research Lab. (USA); **Sudhir B. Trivedi,** Brimrose Corp. of America (USA); **Rama Venkatasubramanian,** RTI International (USA); **Chunlei Wang,** Florida International Univ. (USA); **Priyalal Wijewarnasuriya,** U.S. Army Research Lab. (USA)

TUESDAY 21 APRIL

OPENING REMARKS. . . . . 8:30 AM TO 8:35 AM

Conference Chair: **Nibir K. Dhar,**
U.S. Army Night Vision & Electronic Sensors Directorate (USA)

SESSION 1. . . . . TUE 8:35 AM TO 10:00 AM

Advanced Fuel Cells

Session Chairs: **Nibir K. Dhar,**
U.S. Army Night Vision & Electronic Sensors Directorate (USA);
Achyut K. Dutta, Banpil Photonics, Inc. (USA)

Micro enzymatic biofuel cells: from theoretical to experimental aspect *(Invited Paper)*, Chunlei Wang, Yin Song, Chunhui Chen, Richa Agrawal, Yong Hao, Florida International Univ. (USA) . . . . [9493-1]

Performance study of sugar-yeast-ethanol bio-hybrid fuel cells, Justin P. Jahnke, David M. Mackie, Marcus Benyamin, Sanchao Liu, James J. Sumner, U.S. Army Research Lab. (USA); Rahul Ganguli, Teledyne Scientific Co. (USA) . . . . [9493-2]

Synergic system between photovoltaic module and microbial fuel cell with simultaneous pollution control, Oresta M. Vasyliv, Arterium Corp. (Ukraine); Neelkanth G. Dhere, Univ. of Central Florida (USA) . . . . [9493-3]

Inhomogeneous thermoelectrics: improving overall ZT by localized property variations, Narasimha S. Prasad, NASA Langley Research Ctr. (USA); David C. Nemir, Jan Beck, TXL Group, Inc. (USA); Jay R. Maddux, Patrick J. Taylor, U.S. Army Research Lab. (USA) . . . . [9493-4]

Solar fuel production for a sustainable energy *(Invited Paper)*, Deryn D. Chu, U.S. Army Research Lab. (USA); Nick Wu, West Virginia Univ. (USA); Terry DuBois, Edward J. Plichta, U.S. Army RDECOM CERDEC NVESD (USA) [9493-5]

SESSION 2 . . . . TUE 10:30 AM TO 11:50 AM

Advanced Storage and Battery Technologies

Session Chairs: **Chunlei Wang,** Florida International Univ. (USA);
Achyut K. Dutta, Banpil Photonics, Inc. (USA)

Dielectric properties of low temperature nano engineered Y2/3Cu3Ti4O12 ceramic compound, K. D. Mandal, Sunita Sharma, Shiv S. Yadav, Institute of Technology, Banaras Hindu Univ. (India); M. M. Singh, Narsingh B. Singh, Univ. of Maryland, Baltimore County (USA) . . . . [9493-6]

Effect of organic flux on the colossal dielectric constant of CCTO, Vishnu Razdan, Carnegie-Mellon Univ. (USA); Abhishek Singh, The Pennsylvania State Univ. (USA); Brad Arnold, Fow-Sen Choa, Lisa Kelly, Narsingh B. Singh, Univ. of Maryland, Baltimore County (USA) . . . . [9493-7]

Mapping capacity loss in Al anodes for ultra-lightweight and compact all-solid-state batteries, Chen Gong, Alex Pearse, Univ. of Maryland, College Park (USA); Dmitry Ruzmetov, National Institute of Standards and Technology (USA) and Univ. of Maryland, College Park (USA); Gary Rubloff, Univ. of Maryland, College Park (USA); Norman C. Bartelt, A. Alec Talin, Sandia National Labs. (USA); Marina S. Leite, Univ. of Maryland, College Park (USA) . . . . [9493-8]

Effect of temperature and thickness of the graphene on the hydrogen storage properties, Jie Huang, Chee How Wong, Nanyang Technological Univ. (Singapore) . . . . [9493-9]

Hybridization of lithium-ion batteries and electrochemical capacitors: fabrication and challenges *(Invited Paper)*, Chunlei Wang, Richa Agrawal, Chunhui Chen, Yin Song, Yong Hao, Florida International Univ. (USA) . [9493-10]

Lunch Break and Exhibition Time . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . TUE 1:20 PM TO 3:10 PM

Advanced Harvesting Device and Applications

Session Chairs: **Achyut K. Dutta,** Banpil Photonics, Inc. (USA);
Chunlei Wang, Florida International Univ. (USA)

Carbon microelectromechanical systems (C-MEMS) based microsupercapacitors, Chunlei Wang, Chunhui Chen, Yin Song, Richa Agrawal, Yong Hao, Florida International Univ. (USA) . . . . [9493-11]

Paper-based broadband and wide-angle antireflection coatings for Si and GaAs solar cells, Dongheon Ha, Jeremy N. Munday, Univ. of Maryland, College Park (USA) . . . . [9493-12]

High efficiency solar cells utilizing light-trapping structure, Anil Shrestha, Genki Mizuno, Robert Olah, Banpil Photonics, Inc. (USA); Saif Islam, Banpil Photonics Inc (USA); Achyut K Dutta, Banpil Photonics, Inc. (USA); Nibir K Dhar, Night Vision Lab (USA) . . . . [9493-13]

Pulsed microwave heating method for preparation of dye-sensitized solar cells for greener, faster, cheaper production of photovoltaic materials, Clifford B. Murphy, Roger Williams Univ. (USA); Robert Cotta, The Univ. of Texas at El Paso (USA); Timothy Blais, Roger Williams Univ. (USA); Charles B. Hall, QD Vision, Inc. (USA). . . . . [9493-14]

Piezoelectric energy-harvesting power source and event detection sensors for gun-fired munitions, Jahangir Rastegar, Dake Feng, Omnitek Partners, LLC (USA); Carlos M. Pereira, U.S. Army Armament Research, Development and Engineering Ctr. (USA). . . . . [9493-16]

C-MEMS for bio-sensing applications *(Invited Paper)*, Chunlei Wang, Yin Song, Chunhui Chen, Yong Hao, Richa Agrawal, Florida International Univ. (USA) . . . . [9493-17]

Energy harvesting via ferrofluidic induction, John G. Monroe, Erick S. Vasquez, Zachary S. Aspin, Keisha B. Walters, Matthew J. Berg, Scott M. Thompson, Mississippi State Univ. (USA) . . . . [9493-15]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Interconnection between tricarboxylic acid cycle and energy generation in microbial fuel cell performed by desulfuromonas acetoxidans IMV B-7384, Oresta M. Vasyliv, Arterium Corp. (Ukraine); Olga D. Maslovska, Yaroslav P. Ferensovych, Oleksandr I. Bilyy, Svitlana O. Hnatush, Ivan Franko National Univ. of L'viv (Ukraine) . . . . [9493-18]

Alloyed metal nanoparticles with modulated optical properties for photovoltaics, Allen Chang, Chen Gong, Ellen Cesewski, Marina S. Leite, Univ. of Maryland, College Park (USA). . . . . [9493-19]

A new scattering and absorption enhancement mechanism using quantum dot emission, Yunlu Xu, Jeremy N. Munday, Univ. of Maryland, College Park (USA) . . . . [9493-20]

Power conversion and photodetection through hot carrier generation and collection in a TCO-insulator-metal based device, Tao Gong, Jeremy N. Munday, Univ. of Maryland, College Park (USA). . . . . [9493-21]

The electrical and structural analysis of degraded single junction amorphous silicon solar modules, Gilbert O. Osayemwenre, Univ. of Fort Hare (South Africa). . . . . [9493-22]

Spray-on solar cells using non-toxic nanocrystal inks, Troy K. Townsend, Harry K. Kelderman, St. Mary's College of Maryland (USA) . . . . [9493-23]

How effective are Lambertian dielectric scatterers for light trapping?, Joseph Murray, Jeremy N. Munday, Univ. of Maryland, College Park (USA) . . . . [9493-24]

Enhanced vibration energy harvesting using nonlinear oscillations, Emily K. Engel, Jiaying Wei, Christopher Lee, Franklin W. Olin College of Engineering (USA) . . . . [9493-25]

CONFERENCE 9494A

Wednesday 22 April 2015 • Part of Proceedings of SPIE Vol. 9494

Sensors for Next-Generation Robotics II

Conference Chairs: **Dan Popa,** The Univ. of Texas at Arlington (USA); **Muthu B. J. Wijesundara,** The Univ. of Texas at Arlington Research Institute (USA)

Program Committee: **Ashis G. Banerjee,** GE Global Research (USA); **Ryan R. Close,** U.S. Army RDECOM CERDEC NVESD (USA); **Yong-Lae Park,** Carnegie Mellon Univ. (USA); **Micky Rakotondrabe,** FEMTO-ST (France); **Veronica J. Santos,** Univ. of California, Los Angeles (USA)

WEDNESDAY 22 APRIL

WELCOME REMARKS . . . . 8:00 AM TO 8:10 AM

Conference Chair: **Dan Popa,** The Univ. of Texas at Arlington (USA)

SESSION 1. . . . . WED 8:10 AM TO 10:00 AM

New Sensors for Robots

Session Chair: **Muthu B. J. Wijesundara,** The Univ. of Texas at Arlington Research Institute (USA)

Silicon carbide micro-/nanosystems for sensing and energy applications in harsh environment *(Invited Paper)*, Carlo Carraro, Roya Maboudian, Univ. of California, Berkeley (USA) . . . . [9494-1]

EHD printing of PEDOT: PSS inks for fabricating pressure sensor arrays on flexible substrates, Joshua R. Baptist, Woo Ho Lee, Dan O. Popa, Muthu B. J. Wijesundara, The Univ. of Texas at Arlington (USA) . . . . [9494-2]

Multi-material additive manufacturing of robot components with integrated sensor arrays, Adam Cohen, Matt Saari, Bryan Cox, Matt Galla, Paul Krueger, Edmond Richer, Southern Methodist Univ. (USA). . . . . [9494-3]

Micro-force sensing mobile microrobots for mechanobiology, Wuming Jing, Peter Jaron, Archit Aggarwal, David J. Cappelleri, Purdue Univ. (USA) . . [9494-4]

Magnetoresistive sensors for the next robot generation, Rolf Slatter, Sensitec GmbH (Germany) . . . . [9494-5]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 2 . . . . WED 1:00 PM TO 3:00 PM

Robotic Applications

Session Chair: **Ryan R. Close,** U.S. Army RDECOM CERDEC NVESD (USA)

Perception sensor study for high speed autonomous operations, Anne R. Schneider, Zachary La Celle, Alberto Lacaze, Karl Murphy, Robotic Research LLC (USA); Mark Del Giorno, Del Services, LLC (USA); Ryan R. Close, U.S. Army RDECOM CERDEC NVESD (USA) . . . . [9494-6]

Multi-model sensor and HMI integration with applications in personal robotics, Rommel A. Alonzo, Sven Cremer, Dan O. Popa, The Univ. of Texas at Arlington (USA) . . . . [9494-7]

Robotic situational awareness of actions in human teaming, David Tahmoush, U.S. Army Research Lab. (USA). . . . . [9494-8]

Performance evaluation and clinical applications of 3D plenoptic cameras, Ryan Decker, Azad Shademan, Justin Opfermann, Simon Leonard, Peter C. W. Kim, Axel Krieger, Children's National Medical Ctr. (USA) . . . . [9494-9]

Surface EMG and intra-socket force measurement to control a prosthetic device, Joe D. Sanford, Oguz Yetkin, The Univ. of Texas at Arlington (USA); Carolyn Young, Nicoleta Bugnariu, Rita M. Patterson, Univ. of North Texas Health Science Ctr. at Fort Worth (USA); Dan O. Popa, The Univ. of Texas at Arlington (USA) . . . . [9494-10]

Resolving ranges of layered objects using ground vehicle LiDAR, Jim Hollinger, Brett Kutscher, LSA Autonomy LLC (USA); Ryan R. Close, U.S. Army RDECOM CERDEC NVESD (USA). . . . . [9494-11]

SESSION 3 . . . . WED 3:30 PM TO 4:50 PM

Control

Session Chair: **Ashis Gopal Banerjee,** GE Global Research (USA)

Automated actuation of multiple bubble microrobots using computer-generated holograms, M. Arifur Rahman, Julian Cheng, Qihui Fan, Aaron T. Ohta, Univ. of Hawaii at Manoa (USA) . . . . [9494-12]

An ontology to enable optimized task partitioning in human-robot collaboration for warehouse kitting operations, Ashis G. Banerjee, Andrew Barnes, GE Global Research (USA); Krishnanand N. Kaipa, Jiashun Liu, Shaurya Shriyam, Nadir Shah, Satyandra K. Gupta, Univ. of Maryland, College Park (USA) . . . . [9494-13]

Control of a powered prosthetic device via a pinch gesture interface, Oguz Yetkin, Joe D. Sanford, Dan O. Popa, The Univ. of Texas at Arlington (USA) . . . . [9494-14]

Interaction models between robots wearing sensorized skin and their environment, Md Ahsan Habib, Ioana Corina Bogdan, Dan O. Popa, The Univ. of Texas at Arlington (USA) . . . . [9494-15]

CONFERENCE 9494B

Tuesday 21 April 2015 • Part of Proceedings of SPIE Vol. 9494

Machine Intelligence and Bio-inspired Computation: Theory and Applications IX

Conference Chair: **Misty Blowers,** Air Force Research Lab. (USA)

Program Committee: **Gus Anderson,** MacAulay-Brown, Inc. (USA); **Georgiy M. Levchuk,** Aptima, Inc. (USA); **John A. Marsh,** State Univ. of New York Institute of Technology (USA); **Clare D. Thiem,** Air Force Research Lab. (USA); **Robinson Pino,** U.S. Dept. of Energy (USA); **Daniel Stambovsky,** Air Force Research Lab. (USA); **Jonathan Williams,** Air Force Research Lab. (USA); **Bryant T. Wysocki,** Air Force Research Lab. (USA)

TUESDAY 21 APRIL

SESSION 1. . . . . TUE 1:00 PM TO 2:20 PM

Advances in Fundamental Research

Session Chair: **Misty Blowers,** Air Force Research Lab. (USA)

Evolving spiking neural networks: a novel growth algorithm, J. David Schaffer, Binghamton Univ. (USA) . . . . [9494-16]

Tractability and experimental analysis of a Lotka-Volterra neural network for classification, Christopher L. Sukhu, Joseph E. Stanton, Marc Aylesworth, BAE Systems (USA). . . . . [9494-17]

Collaborative mining and transfer learning for relational data, Georgiy M. Levchuk, Andres Ortiz, Aptima, Inc. (USA) . . . . [9494-18]

Spike encoding for dynamical control system architecture, Bryant T. Wysocki, Thomas A. McEwen, Clare D. Thiem, Nathan R. McDonald, Air Force Research Lab. (USA) . . . . [9494-19]

SESSION 2 . . . . TUE 2:20 PM TO 3:20 PM

Innovations in Applied Research

Session Chair: **Daniel Stambovsky,** Air Force Research Lab. (USA)

Experimental study of a fuzzy-logic-based control approach for maintaining wireless communication connections among multiple mobile robots, Xu Zhong, Stony Brook Univ. (USA); Yu Zhou, State Univ. of New York Institute of Technology (USA) . . . . [9494-20]

Bio-inspired approach for intelligent unattended ground sensors, Nicolas Hueber, Pierre Raymond, Christophe Hennequin, Maxime Perrot, Philippe Voisin, Alexander Pichler, Julien Pichard, Jean-Pierre Moeglin, Institut Franco-Allemand de Recherches de Saint-Louis (France) . . . . [9494-21]

Evaluating data distribution and drift vulnerabilities of machine learning algorithms in secure and adversarial environments part two, Kevin M. Nelson, George E. Corbin, Mark Anania, Matthew G. Kovacs, BAE Systems (USA); Misty Blowers, Air Force Research Lab. (USA) . . . . [9494-22]

SESSION 3 . . . . TUE 3:50 PM TO 4:50 PM

Improved Situational Awareness

Session Chair: **Bryant T. Wysocki,** Air Force Research Lab. (USA)

Subset selection of training data for machine learning: a situational awareness system case study, Sebastien Wong, Mark C. McKenzie, Defence Science and Technology Organisation (Australia). . . . . [9494-23]

Realistic computer network simulation for network intrusion detection dataset generation, Garrett S. Payer, ICF International (USA) . . . . [9494-24]

Change detection in satellite imagery using clustering of sparse approximations (CoSA) over learned feature dictionaries, Daniela I. Moody, Los Alamos National Lab. (USA) . . . . [9494-25]

CONFERENCE 9495

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9495

Three-Dimensional Imaging, Visualization, and Display 2015

Conference Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Conference Co-Chairs: **Osamu Matoba,** Kobe Univ. (Japan); **Manuel Martínez-Corral,** Univ. de València (Spain); **Adrian Stern,** Ben-Gurion Univ. of the Negev (Israel)

Program Committee: **Arun Anand,** Maharaja Sayajirao Univ. of Baroda (India); **Jun Arai,** NHK Japan Broadcasting Corp. (Japan); **V. Michael Bove Jr.,** MIT Media Lab. (USA); **Michael T. Eismann,** Air Force Research Lab. (USA); **Pietro Ferraro,** Istituto Nazionale di Ottica (Italy); **Toshiaki Fujii,** Nagoya Univ. (Japan); **Hong Hua,** College of Optical Sciences, The Univ. of Arizona (USA); **Yi-Pai Huang,** National Chiao Tung Univ. (Taiwan); **Naomi Inoue,** National Institute of Information and Communications Technology (Japan); **Dae-Sik Kim,** SAMSUNG Electronics Co., Ltd. (Korea, Republic of); **Jinwoong Kim,** Electronics and Telecommunications Research Institute (Korea, Republic of); **Thomas J. Naughton,** National Univ. of Ireland, Maynooth (Ireland); **Wolfgang Osten,** Univ. Stuttgart (Germany); **Min-Chul Park,** Korea Institute of Science and Technology (Korea, Republic of); **David J. Rabb,** Air Force Research Lab. (USA); **José Manuel Rodríguez Ramos,** Univ. de La Laguna (Spain); **Sumio Yano,** Shimane Univ. (Japan); **Zeev Zalevsky,** Bar-Ilan Univ. (Israel)

MONDAY 20 APRIL

SESSION 1. . . . . MON 8:10 AM TO 10:00 AM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Portable digital holographic microscope using spherical reference beam and its biomedical applications *(Invited Paper)*, Eriko Watanabe, Kanami Ikeda, Kazuhiro Hoshino, The Univ. of Electro-Communications (Japan) [9495-1]

Three-dimensional microscopy through liquid-lens axial scanning *(Invited Paper)*, Manuel Martínez-Corral, Univ. de València (Spain); Po-Yuan Hsieh, National Chiao Tung Univ. (Taiwan); Ana Isabel Doblas-Exposito, Emilio Sánchez-Ortiga, Genaro Saavedra, Univ. de València (Spain); Yi-Pai Huang, National Chiao Tung Univ. (Taiwan) . . . . [9495-2]

An integral imaging augmented reality display *(Invited Paper)*, Hong Hua, College of Optical Sciences, The Univ. of Arizona (USA); Bahram Javidi, Univ. of Connecticut (USA). . . . . [9495-3]

Integrated fluorescence and phase-contrast digital holographic microscopy for live cell imaging, Xiangyu Quan, Kouichi Nitta, Osamu Matoba, Kobe Univ. (Japan); Peng Xia, Yasuhiro Awatsuji, Kyoto Institute of Technology (Japan) . . . . [9495-4]

SESSION 2 . . . . MON 10:20 AM TO 11:50 AM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Floating information display based on aerial imaging by retro-reflection (AIRR) *(Invited Paper)*, Hirotsugu Yamamoto, Utsunomiya Univ. (Japan) [9495-5]

Recent developments in DFD (depth-fused 3D) display and arc 3D display *(Invited Paper)*, Shiro Suyama, Univ. of Tokushima (Japan); Hirotsugu Yamamoto, Utsunomiya Univ. (Japan) . . . . [9495-6]

Floating three-dimensional image display using micro-mirror array imaging element *(Invited Paper)*, Daisuke Miyazaki, Yuki Maeda, Osaka City Univ. (Japan); Satoshi Maekawa, Parity Innovations Co. Ltd. (Japan). . . . . [9495-7]

Lunch Break . . . . Mon 11:50 am to 12:50 pm

SESSION 3 . . . . MON 12:50 PM TO 2:30 PM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Evaluation of viewing experiences induced by curved 3D display *(Invited Paper)*, Sungchul Mun, Min-Chul Park, Korea Institute of Science and Technology (Korea, Republic of); Sumio Yano, Shimane Univ. (Japan) . . [9495-8]

Accommodation response for integral photography still images, Sumio Yano, Shimane Univ. (Japan); Min-Chul Park, Korea Institute of Science and Technology (Korea, Republic of) . . . . [9495-9]

Effect of brightness in visual discomfort caused from watching 3D and 2D video, Yongwoo Kim, Hang-Bong Kang, The Catholic Univ. of Korea (Korea, Republic of) . . . . [9495-10]

The performances of a supermultiview simulator and the presence of monocular depth sense *(Invited Paper)*, Beom-Ryeol Lee, Jeung-Chul Park, Ilkwon Jeong, Electronics and Telecommunications Research Institute (Korea, Republic of); Jung-Young Son, Konyang Univ. (Korea, Republic of) . . . [9495-11]

SESSION 4 . . . . MON 2:30 PM TO 4:40 PM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Integral imaging for anti-access/area denial environments *(Invited Paper)*, Shih-Chi K. Chen, Abhijit Mahalanobis, Robert Stanfill, Lockheed Martin Missiles and Fire Control (USA); Bahram Javidi, Univ. of Connecticut (USA). . . . [9495-12]

Full-parallax 3D display from single-shot Kinect capture, Seok-Min Hong, Dong-Hak Shin, Byung-Gook Lee, Dongseo Univ. (Korea, Republic of); Adrián Dorado, Genaro Saavedra, Manuel Martínez-Corral, Univ. de València (Spain) . . . . [9495-13]

2D MEMS scanning for lidar with sub-Nyquist sampling, electronics and measurement procedure, Thorsten Giese, Joachim Janes, Fraunhofer-Institut für Siliziumtechnologie (Germany). . . . . [9495-14]

Shaping field for 3D deep tissue microscopy, Hyungsik Lim, Jorge Colon, Hunter College (USA) . . . . [9495-15]

Spatial-spectral volume holographic microscopy, Yuan Luo, National Taiwan Univ. (Taiwan) . . . . [9495-16]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 5 . . . . TUE 8:30 AM TO 10:30 AM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Compact integral three-dimensional imaging device *(Invited Paper)*, Jun Arai, NHK Japan Broadcasting Corp. (Japan); Takayuki Yamashita, Hitoshi Hiura, Masato Masato, Ryohei Funatsu, NHK (Japan Broadcasting Corporation) (Japan); Eisuke Nakasu, NHK Engineering System, Inc. (Japan) . . . . . . [9495-17]

Using perceivable light fields to evaluate the amount of information that autostereoscopic displays need to cast *(Invited Paper)*, Adrian Stern, Ben-Gurion Univ. of the Negev (Israel); Bahram Javidi, Univ. of Connecticut (USA) . . . . [9495-18]

Integral imaging acquisition and processing for human gesture recognition *(Invited Paper)*, Pedro Latorre Carmona, Eva Salvador-Balaguer, Filiberto Pla, Univ. Jaume I (Spain); Bahram Javidi, Univ. of Connecticut (USA). . . . . [9495-19]

Optical barriers in integral imaging monitors through micro-Köhler illumination *(Invited Paper)*, Manuel Martínez-Corral, Héctor Navarro, Genaro Saavedra, Amparo Pons-Martí, Univ. de València (Spain); Raul Martinez-Cuenca, Univ. Jaume I (Spain); Angel Tolosa, AIDO Instituto Tecnológico de Óptica, Color e Imagen (Spain); Bahram Javidi, Univ. of Connecticut (USA) . . . . [9495-20]

SESSION 6 . . . . .TUE 10:30 AM TO 11:50 AM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Digital holographic measurement for voice recording and reproduction *(Invited Paper)*, Osamu Matoba, Hiroki Inokuchi, Kobe Univ. (Japan); Yasuhiro Awatsuji, Kyoto Institute of Technology (Japan) . . . . [9495-21]

High-speed parallel phase-shifting digital holography system using special-purpose computer for image reconstruction *(Invited Paper)*, Takashi Kakue, Tomoyoshi Shimobaba, Tomoyoshi Ito, Chiba Univ. (Japan) . . . . [9495-22]

Implementation of wireless 3D stereo image capture system and 3D exaggeration algorithm for the region of interest, Woonchul C. Ham, Chonbuk National Univ. (Korea, Republic of) . . . . [9495-23]

Lunch Break . . . . Tue 11:50 am to 1:20 pm

SESSION 7 . . . . .TUE 1:20 PM TO 4:30 PM

Session Chairs: **Bahram Javidi,** Univ. of Connecticut (USA); **Jung-Young Son,** Konyang Univ. (Korea, Republic of)

Crosstalks in multiview 3D images *(Invited Paper)*, Jung-Young Son, Konyang Univ. (Korea, Republic of); Beom-Ryeol Lee, Electronics and Telecommunications Research Institute (Korea, Republic of); Min-Chul Park, Thibault Leportier, Korea Institute of Science and Technology (Korea, Republic of) . . . . [9495-24]

Ligthfield superresolution through turbulence *(Invited Paper)*, Juan M. T. Trujillo-Sevilla, Univ. de La Laguna (Spain); Luis Fernando Rodriguez-Ramos, Instituto de Astrofísica de Canarias (Spain); José Manuel Rodríguez Ramos, Univ. de La Laguna (Spain) and ITB-CIBICAN (Spain) . . . . [9495-25]

Spectral analysis of views interpolated by Chroma subpixel downsampling, Avishai Marson, Adrian Stern, Ben-Gurion Univ. of the Negev (Israel) . . [9495-26]

2D MEMS scanning for lidar with sub-Nyquist sampling, set-up and functionality, Joachim Janes, Thorsten Giese, Fraunhofer-Institut für Siliziumtechnologie (Germany) . . . . [9495-27]

FTV standardization for super multiview and free navigation in MPEG *(Invited Paper)*, Masayuki Tanimoto, Nagoya Industrial Science Research Institute (Japan) . . . . [9495-28]

Research on steady-state visual evoked potentials in 3D displays *(Invited Paper)*, Yu-Yi Chien, Chia-Ying Lee, Fang-Cheng Lin, Yi-Pai Huang, Han-Ping D. Shieh, National Chiao Tung Univ. (Taiwan). . . . . [9495-29]

Reconstruct holographic 3D objects by double phase hologram *(Invited Paper)*, Chih-Hung Ting, National Chiao Tung Univ. (Taiwan); Koki Wakunami, Kenji Yamamoto, National Institute of Information and Communications Technology (Japan); Yi-Pai Huang, National Chiao Tung Univ. (Taiwan) [9495-30]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Format matching using multiple-planes pseudoscopic-to-orthoscopic conversion for 3D integral imaging display, Xin Shen, Xiao Xiao, Univ. of Connecticut (USA); Manuel Martínez-Corral, Univ. de València (Spain); Bahram Javidi, Univ. of Connecticut (USA). . . . . [9495-31]

A comparison of a DEM's derived from DS2, LIDAR and Kompsat-3, Eman S. Altunaiji, Emirates Institution for Advanced Science and Technology (United Arab Emirates) . . . . [9495-32]

Color image authentication scheme via multispectral photon-counting double random phase encoding, Inkyu Moon, Chosun Univ. (Korea, Republic of) . . . . [9495-33]

Parallel reconstruction of multiple depth slice images with focused parts in integral imaging via graphics processing unit, Inkyu Moon, Faliu Yi, Chosun Univ. (Korea, Republic of) . . . . [9495-34]

Optimizing the diffraction efficiency of LCOS-based holography with anomalous reflection by gradient meta-surface, Chuan Shen, Kaifeng Liu, Sui Wei, Lei Ni, Hao Wang, Anhui Univ. (China) . . . . [9495-35]

Phase retrieval using iterative Fourier transform and convex optimization algorithm, Zhang Fen, Cheng Hong, Quanbing Zhang, Sui Wei, Anhui Univ. (China) . . . . [9495-36]

A novel hybrid phase retrieval algorithm for partially coherent light illuminations, Hong Cheng, Fen Zhang, Sui Wei, Yanliu Liu, Yapin Chen, Anhui Univ. (China) . . . . [9495-37]

3D high speed characterization of phase and amplitude objects using the transport of intensity equation, Georges T. Nehmetallah, Thanh Nguyen, The Catholic Univ. of America (USA); Ahmad Darudi, Peyman Soltani, Univ. of Zanjan (Iran, Islamic Republic of) . . . . [9495-38]

3D subsurface imaging of crustal rocks using components of electromagnetic radiations based on Maxwell theory prior seismic events in situ, Umesh P. Verma, Ranvir N. Nandan, Patna Science College (India). . . . . [9495-39]

Color reconstruction of computer-generated hologram for real scenes using a light field camera, Yutaka Endo, Takashi Kakue, Tomoyoshi Shimobaba, Tomoyoshi Ito, Chiba Univ. (Japan) . . . . [9495-40]

Compressive holography reconstruction using parallel phase-shifting interferometry, Cheng Zhang, Chuan Shen, Hong Cheng, Fen Zhang, Kaifeng Liu, Quanbing Zhang, Sui Wei, Anhui Univ. (China). . . . . [9495-41]

Viewing zone control of super multi-view display with directional backlight, Kenji Hirano, Nagaoka Univ. of Technology (Japan). . . . . [9495-42]

The use of 3D scanning for sporting applications, Kevin J. Friel, Pann Ajjimaporn, Jeremy Straub, Scott Kerlin, Univ. of North Dakota (USA) . [9495-43]

The use of 3D scanning for wellness assessment purposes, Pann Ajjimaporn, Kevin J. Friel, Jeremy Straub, Scott Kerlin, Univ. of North Dakota (USA) . . . . [9495-44]

Gesture recognition and space-division multiplexing enabled fog based interactive 360-degree viewable display, Praneeth K. Chakravarthula, Indian Institute of Technology Madras (India); Pattie Maes, Massachusetts Institute of Technology (USA) . . . . [9495-45]

Projection type transparent 3D display using active screen, Hiroki Kamoshita, Nagaoka Univ. of Technology (Japan) . . . . [9495-46]

Noise reduction in holographic reconstruction by combining two spatial light modulators, Thibault Leportier, Min-Chul Park, Korea Institute of Science and Technology (Korea, Republic of); Jung-Young Son, Konyang Univ. (Korea, Republic of) . . . . [9495-47]

Evaluating visual discomfort in stereoscopic projection-based CAVE system with a close viewing distance, Weitao Song, Beijing Institute of Technology (China) and Univ. of Connecticut (USA); Dongdong Weng, Dan Feng, Yue Liu, Yongtian Wang, Beijing Institute of Technology (China) . [9495-48]

Conditions in order to maintain the viewing zone in autostereoscopic display, Seon Kyu Yoon, Korea Institute of Science and Technology (Korea, Republic of) and Korea Univ. (Korea, Republic of); Sung Kyu Kim, Korea Institute of Science and Technology (Korea, Republic of) . . . . [9495-49]

Impact of lighting and attire on 3D scanner performance, Dakota J. Feist, Jeremy Straub, Scott Kerlin, Univ. of North Dakota (USA) . . . . [9495-50]

Integrating visible light 3D scanning into the everyday world, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9495-51]

CONFERENCE 9496

Wednesday 22 April 2015 • Proceedings of SPIE Vol. 9496

Independent Component Analyses, Compressive Sampling, Large Data Analyses (LDA), Neural Networks, Biosystems, and Nanoengineering XIII

Conference Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Conference Co-Chairs: **Liyi Dai,** U.S. Army Research Office (USA); **Yufeng Zheng,** Alcorn State Univ. (USA)

Program Committee: **Shun-ichi Amari,** RIKEN (Japan); **Richard G. Baraniuk,** Rice Univ. (USA); **John J. Benedetto,** Univ. of Maryland, College Park (USA); **Henry Chu,** Univ. of Louisiana at Lafayette (USA); **Ronald R. Coifman,** Yale Univ. (USA); **John Daugman,** Univ. of Cambridge (United Kingdom); **David Donohoe,** Stanford Univ. (USA); **Ronald G. Driggers,** St. Johns Optical Systems (USA); **Jide Familoni,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Fredric M. Ham,** Florida Institute of Technology (USA); **Yutaka Hata,** Univ. of Hyogo (Japan); **Charles C. Hsu,** Trident Systems Inc. (USA); **Tzyy-Ping Jung,** Univ. of California, San Diego (USA); **Marc W. Kirschner,** Harvard Medical School (USA); **Keith A. Krapels,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Horacio Lamela,** Univ. Carlos III de Madrid (Spain); **Joseph S. Landa,** BriarTek, Inc. (USA); **Douglas A. Lauffenburger,** Massachusetts Institute of Technology (USA); **Soo-Young Lee,** KAIST (Korea, Republic of); **Kevin W. Lyons,** National Institute of Standards and Technology (USA); **Anke D. Meyer-Bäse,** The Florida State Univ. (USA); **Uwe Meyer-Baese,** The Florida State Univ. (USA); **Francesco Carlo Morabito,** Univ. Mediterranea di Reggio Calabria (Italy); **Hiroshi Nakajima,** OMRON Corp. (Japan); **Hyung-Min Park,** Sogang Univ. (Korea, Republic of); **Kitt C. Reinhardt,** Air Force Office of Scientific Research (USA); **Zuowei Shen,** National Univ. of Singapore (Singapore); **Metin Sitti,** Carnegie Mellon Univ. (USA); **Jan-Olov Stromberg,** Royal Institute of Technology (Sweden); **John Tangney,** Office of Naval Research (USA); **Emmanuel Vincent,** IRISA / INRIA Rennes (France); **Nadarajen A. Vydelingum,** National Institutes of Health (USA); **Lipo Wang,** Nanyang Technological Univ. (Singapore); **Olaf Wolkenhauer,** Univ. Rostock (Germany); **Donald C. Wunsch II,** Missouri Univ. of Science and Technology (USA); **Ning Xi,** Michigan State Univ. (USA); **Takeshi Yamakawa,** Fuzzy Logic Systems Institute (Japan); **Yiping Zhao,** The Univ. of Georgia (USA); **Xiaowei Zhuang,** Harvard Univ. (USA)

THURSDAY 23 APRIL

SESSION 1. . . . . THU 8:00 AM TO 9:40 AM

Biomedical Wellness Applications

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Remote stress detection using visible (RGB) camera, Balvinder Kaur, Sophia Moses, Megha Luthra, Vasiliki N. Ikonomidou, George Mason Univ. (USA) . . . . [9496-1]

Breast lesion segmentation using a three-dimensional active contours without edges approach with a GPGPU implementation, Anke Meyer-Baese, Florida State Univ. (USA). . . . . [9496-2]

Remotely detected differential pulse transit time as a stress indicator, Balvinder Kaur, Elizabeth Tarbox, Marty Cissel, Sophia Moses, Megha Luthra, Nhien Tran, Misha Vaidya, Vasiliki N. Ikonomidou, George Mason Univ. (USA) . . . . [9496-3]

High accuracy optical flow estimation based on robustification variants and novel computer-aided diagnosis systems applied to breast MRI, Anke Meyer-Baese, Florida State Univ. (USA) . . . . [9496-4]

Catheter ultrasound for cross-sectional imaging and drug delivery to vessel wall, John A. Hossack, Univ. of Virginia (USA) . . . . [9496-5]

SESSION 2 . . . . .THU 9:40 AM TO 10:40 AM

System Biology

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Quantitative analysis of integrated chromosome 19 transcriptomic and proteomic data sets derived from glioma cancer stem-cell lines, Anke Meyer-Baese, Florida State Univ. (USA) . . . . [9496-6]

Dynamical complex network theory applied to the therapeutics of brain malignancies, Anke Meyer-Baese, Florida State Univ. (USA) . . . . [9496-7]

A new EEG measure using the 1-D cluster variation method, Alianna J. Maren, Themasis Associates (USA) . . . . [9496-26]

SESSION 3 . . . . THU 11:00 AM TO 12:40 PM

Learning Theory and Applications

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Reducing weight precision of convolutional neural networks towards large-scale on-chip image recognition, Zhengping Ji, Ilia Ovsiannikov, Yibing Wang, Lilong Shi, Qiang Zhang, Samsung Semiconductor, Inc. (USA) . . . . [9496-8]

An evaluation into the effectiveness of machine learning algorithms in traffic pattern prediction using field and simulation data, Nnanna N. Ekedebe, Nicolas Dolphin, Towson Univ. (USA) . . . . [9496-9]

A generalized LDA framework through 6W, Jeffrey C. Jenkins, The Catholic Univ. of America (USA); Rutger Van Bergem, George Mason Univ. (USA); Charles Sweet, LoftMind, Inc. (USA); Eveline Vietsch, Georgetown Univ. Medical Ctr. (USA); Harold H. Szu, The Catholic Univ. of America (USA); Masud Cader, American Univ. (USA); Dalila Benachenhou, George Washington Univ. (USA) . . . . [9496-10]

Earth mover's distances of feature vectors in large data analyses, Henry Chu, Anurag Singh, Michael A. Pratt, Univ. of Louisiana at Lafayette (USA) . . . . [9496-11]

Compressive sensing solutions through minimax optimization, Liyi Dai, U.S. Army Research Office (USA) . . . . [9496-12]

Lunch Break and Exhibition Time . . . . Thu 12:40 pm to 2:00 pm

SESSION 4 . . . . .THU 2:00 PM TO 3:00 PM

Smart Sensor Systems, Miniaturization, and Applications

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Hypothesis on human eye perceiving optical spectrum rather than an image, Yufeng Zheng, Alcorn State Univ. (USA); Harold H. Szu, The Catholic Univ. of America (USA) . . . . [9496-13]

Radar sensing while optical displaying, Harold H. Szu, Charles C. Hsu, The Catholic Univ. of America (USA); Michael J. Wardlaw, Office of Naval Research (USA); Jefferson M. Willey, U.S. Naval Research Lab. (USA) . . . . [9496-14]

Optical sensing cameras, Harold H. Szu, The Catholic Univ. of America (USA); Jae Hoon Cha, A. Lynn Abbott, Virginia Polytechnic Institute and State Univ. (USA); Keith A. Krapels, The Univ. of Memphis (USA) . . . . [9496-15]

SESSION 5 . . . . THU 3:30 PM TO 5:30 PM

Unsupervised Learning and ICA

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

Automatic organization and signal processing of databases, Ronald R. Coifman, Plain Sight Systems, Inc. (USA). . . . . [9496-16]

VoIP attacks detection engine based on neural network, Jakub Safarik, Pavol Partila, Jaromir Tovarek, Martin Mikulec, Miroslav Voznak, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . . [9496-17]

Thermal image enhancement based on blind source separation and multiple spectral measurements, Jae Hoon Cha, U.S. Army Night Vision & Electronic Sensors Directorate (USA); A. Lynn Abbott, Virginia Polytechnic Institute and State Univ. (USA); Harold H. Szu, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9496-18]

Auxiliary function approach to independent component analysis and independent vector analysis, Nobutaka Ono, National Institute of Informatics (Japan). . . . . [9496-19]

How do artificial neural networks (ANNs) compare to partial least squares (PLS) for spectral interference correction in optical emission spectrometry?, Z. Li, X. Zhang, Vassili Karanassios, Univ. of Waterloo (Canada) . . . . [9496-20]

Biomining: bridging the gap between health and security LDA, Jeffrey C. Jenkins, The Catholic Univ. of America (USA); Christopher Frenchi, Christopher Newport Univ. (USA); Charles Sweet, LoftMind, Inc. (USA); Binh Q. Tran, Harold H. Szu, The Catholic Univ. of America (USA) . . . . [9496-21]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Detection of cardiac activity changes from human speech, Jaromir Tovarek, Pavol Partila, Miroslav Voznak, Jakub Safarik, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . . [9496-22]

FPGA-based realtime blind source separation with principal component analysis, Matthew Wilson, Uwe Meyer-Baese, Florida State Univ. (USA) . . . . [9496-23]

Independent component analysis algorithm FPGA design to perform real-time blind source separation, Uwe Meyer-Baese, Crispin Odom, Florida State Univ. (USA) . . . . [9496-24]

FRIDAY 24 APRIL

SESSION 6 . . . . .FRI 8:00 AM TO 12:00 PM

Award Session

Session Chair: **Harold H. Szu,** U.S. Army Research Office (USA)

CONFERENCE 9497

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9497

Mobile Multimedia/Image Processing, Security, and Applications 2015

Conference Chairs: **Sos S. Agaian,** The Univ. of Texas at San Antonio (USA); **Sabah A. Jassim,** The Univ. of Buckingham (United Kingdom); **Eliza Yingzi Du,** Qualcomm Inc. (USA)

Program Committee: **David Akopian,** The Univ. of Texas at San Antonio (USA); **Salim Alsharif,** Univ. of South Alabama (USA); **Vijayan K. Asari,** Univ. of Dayton (USA); **Cesar Bandera,** BanDeMar Networks (USA); **Chang Wen Chen,** Univ. at Buffalo (USA); **Reiner Creutzburg,** Fachhochschule Brandenburg (Germany); **Stephen P. DelMarco,** BAE Systems (USA); **Frederic Dufaux,** Telecom ParisTech (France); **Touradj Ebrahimi,** Ecole Polytechnique Fédérale de Lausanne (Switzerland); **Erlan H. Feria,** College of Staten Island (USA); **Phalguni Gupta,** Indian Institute of Technology Kanpur (India); **Yo-Ping Huang,** National Taipei Univ. of Technology (Taiwan); **Jacques Koreman,** Norwegian Univ. of Science and Technology (Norway); **Maryline Maknavicius,** TELECOM & Management SudParis (France); **Alessandro Neri,** Univ. degli Studi di Roma Tre (Italy); **Cheryl L. Resch,** Johns Hopkins Univ. Applied Physics Lab. (USA); **Haleh Safavi,** NASA Goddard Space Flight Ctr. (USA); **Harin Sellahewa,** The Univ. of Buckingham (United Kingdom); **Yuri Shukuryan,** National Academy of Sciences of Armenia (Armenia); **Viacheslav Voronin,** Don State Technical Univ. (Russian Federation); **Yue Wu,** Tufts Univ. (USA); **Yicong Zhou,** Univ. of Macau (Macao, China)

MONDAY 20 APRIL

SESSION 1. . . . . .MON 8:00 AM TO 12:10 PM

Innovative Image Processing Techniques

Session Chair: **Sos S. Agaian,** The Univ. of Texas at San Antonio (USA)

Segmentation of textured images based on descriptor's of local approximations, Alexander I. Sherstobitov, Don State Technical Univ. (Russian Federation); Dmitry V. Timofeev, South Federal Univ. (Russian Federation); Vladimir I. Marchuk, Don State Technical Univ. (Russian Federation); Sos S. Agaian, The Univ. of Texas at San Antonio (USA); Vyacheslav V. Voronin, Don State Technical Univ. (Russian Federation); Karen O. Egiazarian, Tampere Univ. of Technology (Finland). . . . .[9497-1]

Color image retrieval and analysis, Chen Gao, Karen Panetta, Tufts Univ. (USA); Sos S. Agaian, The Univ. of Texas at San Antonio (USA) . . . .[9497-2]

A nonparametric hypothesis testing approach to wavelet domain image fusion, Stephen P. DelMarco, BAE Systems (USA) . . . .[9497-3]

Improved patch-based learning for image deblurring, Dong Bo, Haopeng Zhang, Zhiguo Jiang, Beihang Univ. (China). . . . .[9497-4]

Intensity and resolution enhancement of local regions for object detection and tracking in wide area surveillance, Evan Krieger, Vijayan K. Asari, Saibabu Arigela, Theus Aspiras, Univ. of Dayton (USA) . . . .[9497-5]

Image restoration using 2D autoregressive texture model and structure curve construction, Viacheslav V. Voronin, Vladimir I. Marchuk, Alexander I. Sherstobitov, Don State Technical Univ. (Russian Federation); Ilya Svirin, CJSC "Nordavind" (Russian Federation); Sos S. Agaian, The Univ. of Texas at San Antonio (USA); Karen O. Egiazarian, Tampere Univ. of Technology (Finland). . . . .[9497-6]

Real-time, non-distortive multimedia content modification over TCP/IP networks, James C. Collins, Sos S. Agaian, The Univ. of Texas at San Antonio (USA) . . . .[9497-7]

European activities in civil applications of drones: an overview of remotely piloted aircraft systems (RPAS), Reiner Creutzburg, Fachhochschule Brandenburg (Germany) . . . .[9497-8]

Investigation of methods to search for the boundaries on the image and their use on lung hardware of methods finding saliency map, Evgeny Semenishchev, South-Russian State Univ. of Economics and Service (Russian Federation) . . . .[9497-9]

3D cluster-driven bilateral filter for speckle reduction in ultrasound images, Jinshan Tang, Zhilong Hu, Michigan Technological Univ. (USA) . . . . . .[9497-10]

Image enhancement using hierarchical Bayesian image expansion super resolution, Timothy Whitney, Jeremy Straub, Ronald Marsh, Univ. of North Dakota (USA). . . . .[9497-11]

Lunch Break . . . . .Mon 12:10 pm to 1:10 pm

SESSION 2 . . . . .MON 1:10 PM TO 3:10 PM

Security and Privacy

Session Chair: **Sabah A. Jassim,** The Univ. of Buckingham (United Kingdom)

Encryption for confidentiality of the network and influence of this to the quality of streaming video through network, Lukas Sevcik, Dominik Uhrin, Jaroslav Frnda, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . .[9497-12]

Tensor transform-based method of image encryption, Artyom M. Grigoryan, Bryan A. Wiatrek, Sos S. Agaian, The Univ. of Texas at San Antonio (USA) . . . .[9497-13]

On a simulation study of cyber-attacks on vehicle-to-infrastructure communication in intelligent transportation system, Nnanna N. Ekedebe, Wei Yu, Towson Univ. (USA); Houbing Song, West Virginia Univ. (USA); Chao Lu, Towson Univ. (USA). . . . .[9497-14]

Transform domain steganography with blind source separation, Ismail I. Jouny, Lafayette College (USA). . . . .[9497-15]

Information security trades in tactical wireless networks, Michael T. Kurdziel, Harris Corp. (USA) and Rochester Institute of Technology (USA); John A. Alvermann, Harris Corp. (USA). . . . .[9497-16]

A better detection of 2LSB steganography via standard deviation of the extended pairs of values, Omed S. Khalind, Benjamin Aziz, Univ. of Portsmouth (United Kingdom). . . . .[9497-37]

SESSION 3 . . . . MON 3:40 PM TO 5:00 PM

Detection and Localization

Session Chair: **Eliza Yingzi Du,** Qualcomm Inc. (USA)

Capon-based single snapshot DOA estimation in monostatic MIMO radar, Aboulnasr Hassanien, Moeness G. Amin, Yimin D. Zhang, Fauzia Ahmad, Villanova Univ. (USA). . . . .[9497-17]

Building occupant and asset localization and tracking using visible light communication, Kofi Nyarko, Samuel Mbugua, Christian Emiyah, Morgan State Univ. (USA) . . . .[9497-18]

Experimental studies of high-accuracy RFID localization with channel impairments, Eric Pauls, Yimin D. Zhang, Villanova Univ. (USA). . . . . .[9497-19]

Efficient target tracking with an ad-hoc networks of omni-directional sensors, Kalin Atanassov, Qualcomm MEMS Technologies, Inc. (USA); William S. Hodgkiss, Univ. of California, San Diego (USA) . . . .[9497-20]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 4 . . . . .TUE 8:00 AM TO 9:20 AM

Implementation and Applications

Session Chair: **Sos S. Agaian,** The Univ. of Texas at San Antonio (USA)

Nonparametric spectrum estimation using generalized coprime sampling, Si Qin, Yimin D. Zhang, Moeness G. Amin, Villanova Univ. (USA) . . . . . [9497-21]

On an investigation into intelligent transportation system (its) safety, and traffic efficiency applications, Nnanna N. Ekedebe, Nicolas Dolphin, Towson Univ. (USA). . . . . [9497-22]

Video sensor calibration by invoking video synopsis approach with external constraint criteria, Sumit Chakravarty, New York Institute of Technology (USA); Sherry Zhu, Nanjing Univ. of Post and Telecommunications (China) . . . [9497-35]

On the universe's cybernetics duality behavior, Erlan H. Feria, The College of Staten Island of the City Univ. of New York (USA) . . . . [9497-34]

SESSION 5 . . . . TUE 9:20 AM TO 11:30 AM

Modulation and Channel Estimation

Session Chair: **Sabah A. Jassim,**
The Univ. of Buckingham (United Kingdom)

A modified CMA equalizer for SOQPSK for aeronautical telemetry, Arlene Cole-Rhodes, Morgan State Univ. (USA). . . . . [9497-23]

Investigating inner and outer convolutional code structures in serially concatenated systems, John W. Nieto, Harris Corp. (USA) . . . . [9497-24]

On the use of serial concatenated codes as applied to quasi-coherent CPM, James A. Norris, John W. Nieto, Harris Corp. (USA) . . . . [9497-25]

Estimated availability of new wideband HF communications technology at high latitudes, Vivianne Jodalen, Norwegian Defence Research Establishment (Norway) . . . . [9497-26]

New cognitive detection techniques for multimedia signals, Sumit Chakravarty, New York Institute of Technology (USA); Yixuan Sun, Nanjing Univ. of Post and Telecommunications (China) . . . . [9497-36]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

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Simulating the performance of switched diversity with post-examining selection, Richard J. Wright, Harris Corp. (USA) . . . . [9497-27]

Parsimonious sidelobe control for transmit beamforming in MIMO radar with multidimensional arrays, Aboulnasr Hassanien, Yimin D. Zhang, Moeness G. Amin, Fauzia Ahmad, Villanova Univ. (USA) . . . . [9497-28]

Quaternion Fourier transform-based prediction of coding region in DNA sequences, Artyom M. Grigoryan, Sos S. Agaian, The Univ. of Texas at San Antonio (USA) . . . . [9497-29]

Inpainting for videos with dynamic objects using texture and structure reconstruction, Viacheslav V. Voronin, Vladimir I. Marchuk, Nikolay V. Gapon, Don State Technical Univ. (Russian Federation); Andrey Zhuravlev, Bauman Moscow State Technical Univ. (Russian Federation); Sos S. Agaian, The Univ. of Texas at San Antonio (USA); Karen O. Egiazarian, Tampere Univ. of Technology (Finland). . . . . [9497-30]

Assessment of heart rate variability based on mobile device for planning physical activity, Ilya Svirin, CJSC "Nordavind" (Russian Federation); Nadezhda Nabilskaya, TSEZIS LLC (Russian Federation); Vyacheslav V. Voronin, Don State Technical Univ. (Russian Federation) . . . . [9497-31]

Network synchronization for secure mobile communication, Chang-Woo Park, Korea Electronics Technology Institute (Korea, Republic of). . . . . [9497-32]

CONFERENCE 9498

Tuesday 21 April 2015 • Proceedings of SPIE Vol. 9498

Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2015

Conference Chair: **Jerome J. Braun** (USA)

Program Committee: **Sheela V. Belur,** The Van Dyke Technology Group, Inc. (USA); **David P. Benjamin,** Pace Univ. (USA); **Belur V. Dasarathy,** Information Fusion Technologies (USA); **Michael Heizmann,** Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); **Charles F. Hester,** U.S. Army Research, Development and Engineering Command (USA); **Mieczyslaw M. Kokar,** Northeastern Univ. (USA); **Damian M. Lyons,** Fordham Univ. (USA); **Mirela Popa,** Chemring Detection Systems, Inc. (USA); **Firooz A. Sadjadi,** Lockheed Martin Maritime Systems & Sensors (USA); **Pramod Kumar Varshney,** Syracuse Univ. (USA); **Shanchieh Jay Yang,** Rochester Institute of Technology (USA)

TUESDAY 21 APRIL

SESSION 1. . . . . .TUE 9:00 AM TO 10:20 AM

Information Fusion Approaches and Algorithms I

Session Chairs: **Jerome J. Braun,** (USA); **Damian M. Lyons,** Fordham Univ. (USA)

An asset valuation approach using fuzzy logic, Henry Leung, Univ. of Calgary (Canada) . . . . [9498-1]

Reliable sources and uncertain decisions in multisensor systems, Christian P. Minor, Nova Research, Inc. (USA); Kevin J. Johnson, U.S. Naval Research Lab. (USA) . . . . [9498-2]

Integration of a sense and avoid (SAA) sensor fusion system architecture in a UAS in the NAS human-in-the-loop (HITL) experiment simulation platform, William L. Fehlman II, Maria Consiglio, NASA Langley Research Ctr. (USA) . . . . [9498-3]

STAC: a new fusion model for complex scene characterization and semantic mapping, Zsolt Kira, Alan R. Wagner, Christopher J. Kennedy, Jason Zutty, Grady Tuell, Georgia Tech Research Institute (USA) . . . . . . [9498-4]

SESSION 2 . . . . .TUE 10:50 AM TO 12:10 PM

Information Fusion Approaches and Algorithms II

Session Chairs: **David Paul Benjamin,** Pace Univ. (USA); **Damian M. Lyons,** Fordham Univ. (USA)

Better-than-the-best fusion algorithm with application in human activity recognition, Nayeff Njjar, Shalabh Gupta, Univ. of Connecticut (USA) . . [9498-5]

A theoretical performance analysis of discrete data classification when fusing two features, Robert S. Lynch, Analytic Information Fusion Systems, LLC (USA) and Univ. of Connecticut (USA); Peter K. Willett, Univ. of Connecticut (USA) . . . . [9498-6]

Flight plan optimization, Anoop Dharmaseelan, Flight Focus (Singapore) and SIM Univ. (Singapore); Keyne D. Adistambha, Flight Focus (Singapore); Terence K. L. Goh, William Phay, SIM Univ. (Singapore) . . . . [9498-7]

Multisensory information-based real-world multimodal social interactions between a humanoid robot and a virtual human, S. M. Mizanoor Rahman, Clemson Univ. (USA). . . . .[9498-16]

Lunch Break and Exhibition Time . . . . Tue 12:10 pm to 1:40 pm

SESSION 3 . . . . TUE 1:40 PM TO 3:00 PM

Information Fusion Approaches and Algorithms III

Session Chairs: **Mirela Popa,** Chemring Detection Systems, Inc. (USA); **Charles F. Hester,** U.S. Army Research, Development and Engineering Command (USA)

Pragmatic open space box utilization: asteroid survey model using distributed objects management based articulation (DOMBA), Atif F. Mohammad, The Univ. of North Dakota (USA); Jeremy Straub, Univ. of North Dakota (USA). . . . . [9498-8]

Gaussian process based modeling and design of experiments for sensor calibration in drifting environments, Feng Yang, Zongyu Geng, Nianqiang Wu, West Virginia Univ. (USA) . . . . [9498-9]

Uncertainty modeling using copulas for classification, Onur Ozdemir, Boston Fusion Corp. (USA); Sora Choi, Syracuse Univ. (USA); Thomas G. Allen, Boston Fusion Corp. (USA); Pramod K. Varshney, Syracuse Univ. (USA); Karla K. Spriestersbach, Missile Defense Agency (USA) . . . . [9498-10]

Relationships between trust and power assistance levels in human-robot collaborative manipulation of objects with power-assist, S. M. Mizanoor Rahman, Clemson Univ. (USA); Ryojun Ikeura, Mie Univ. (Japan) . . . . . [9498-11]

SESSION 4 . . . . TUE 3:30 PM TO 4:50 PM

Information Fusion and Robotics

Session Chairs: **Damian M. Lyons,** Fordham Univ. (USA); **Jerome J. Braun** (USA)

Effects of using a 3D model on the performance of vision algorithms, Paul Benjamin, Pace Univ. (USA); Damian M. Lyons, Fordham Univ. (USA); Robert Lynch, Analytic Information Fusion Systems, LLC (USA) and Univ. of Connecticut (USA). . . . . [9498-12]

Combining voice and gesture recognition for improved control of UGVs and UAVs, Adrian Stoica, Christopher Assad, Michael Wolf, Jaakko T. Karras, Jet Propulsion Lab. (USA); Marco Arena, Politecnico di Torino (Italy); Randi Williams, Univ. of Maryland, Baltimore (USA) . . . . [9498-13]

Evaluation of parallel reduction strategies for fusion of sensory information from a robot team, Damian M. Lyons, Joseph Leroy, Fordham Univ. (USA) . . . . [9498-14]

Performance measurements of a mobile manipulator, Roger V. Bostelman, Jeremy A. Marvel, National Institute of Standards and Technology (USA) . . . . [9498-15]

PANEL DISCUSSION. . . . . .4:50 PM TO 5:30 PM

Moderator: **Jerome J. Braun** (USA)

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

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Novel design of a reduced sensory information-based small size and low weight variable impedance actuator for soft and compliant robotics applications, S. M. Mizanoor Rahman, Clemson Univ. (USA) . . . . [9498-17]

CONFERENCE 9499

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9499

Next-Generation Analyst III

Conference Chairs: **Barbara D. Broome,** U.S. Army Research Lab. (USA); **Timothy P. Hanratty,** U.S. Army Research Lab. (USA); **David L. Hall,** The Pennsylvania State Univ. (USA); **James Llinas,** Univ. at Buffalo (USA)

Program Committee: **Nina M. Berry,** Sandia National Labs., California (USA); **John S. Eicke,** U.S. Army Research Lab. (USA); **James Fink,** U.S. Army Intelligence Ctr. of Excellence (USA); **James Hendler,** Rensselaer Polytechnic Institute (USA); **Bob Madahar,** Defence Science and Technology Lab. (United Kingdom); **Paul Sajda,** Columbia Univ. (USA); **Alan Steinberg,** Georgia Tech Research Institute (USA); **Edward L. Waltz,** BAE Systems (USA)

MONDAY 20 APRIL

SESSION 1. . . . . MON 1:30 PM TO 3:10 PM

Exploitation of Social Media

Session Chair: **Barbara D. Broome,** U.S. Army Research Lab. (USA)

Hypothesis testing from social data, Md. Tanvir Al Amin, Univ. of Illinois at Urbana-Champaign (USA); Lance M. Kaplan, Jemin George, U.S. Army Research Lab. (USA); Boleslaw Szymanski, Rensselaer Polytechnic Institute (USA); Tarek Abdelzaher, Univ. of Illinois at Urbana-Champaign (USA) . . [9499-1]

Challenges in the use of social media data for the next generation analyst, William R. Grace, Robert Leskovich, The Pennsylvania State Univ. (USA) . . . . [9499-2]

Localized emotional barometer: sentiment analysis using Yik Yak data, W. Robert Leskovich, The Pennsylvania State Univ. (USA) . . . . [9499-3]

Employing socially driven techniques for framing, contextualization, and collaboration in complex analytical threads, Arthur Wollocko, Michael Farry, Martin Voshell, Michael Jenkins, Charles River Analytics, Inc. (USA) . . . . [9499-4]

Social network analysis realization and exploitation, Jack Davenport, James J. Nolan, Decisive Analytics Corp. (USA) . . . . [9499-5]

SESSION 2 . . . . MON 3:40 PM TO 5:00 PM

Advance Concepts I

Session Chair: **Timothy P. Hanratty,** U.S. Army Research Lab. (USA)

Interactive geospatial integration of multi-INT data, Craig A. Knoblock, Yao-Yi Chiang, Pedro Szekely, The Univ. of Southern California (USA) . . [9499-6]

Classification of short-lived objects using an adaptive assistance system, Nadia El Bekri, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany) . . . . [9499-7]

Recognition of human-vehicle interactions in group activities via multi-attributed semantic message generation, Vinayak Elangovan, Amir Shirkhodaie, Tennessee State Univ. (USA) . . . . [9499-8]

Topic periodicity discovery from text data, Jingjing Wang, Univ. of Illinois at Urbana-Champaign (USA); Hongbo Deng, Yahoo! Inc. (USA); Jiawei Han, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9499-9]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

TUESDAY 21 APRIL

SESSION 3 . . . . TUE 8:10 AM TO 9:50 AM

Emerging Technology

Session Chair: **Timothy P. Hanratty,** U.S. Army Research Lab. (USA)

A survey of tools and resources for the next generation analyst, David L. Hall, Jacob L. Graham, Emily Catherman, The Pennsylvania State Univ. (USA) . . . . [9499-10]

Addressing information management and dissemination challenges for the next-generation analyst, Jesse Kovach, Laurel C. Sadler, Niranjan Suri, Robert P. Winkler, U.S. Army Research Lab. (USA) . . . . [9499-11]

Next generation data harmonization, Justin M. Del Vecchio, CUBRC (USA) . . . . [9499-12]

Intelligence reach for expertise (IREx), James R. Schoening, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); Yonatan Schreiber, CUBRC (USA); Christina Hadley, QED Systems, LLC (USA). [9499-13]

Utilizing context for improved threat analysis, Eric G. Little, Geoff Gross, Modus Operandi, Inc. (USA) . . . . [9499-14]

SESSION 4 . . . . TUE 10:20 AM TO 12:00 PM

Human Machine Interaction

Session Chair: **David L. Hall,** The Pennsylvania State Univ. (USA)

Collaborative interactive visualization: exploratory concept, Marielle Mokhtari, Valérie Lavigne, Frédéric Drolet, Defence R&D - Valcartier (Canada) . . . . [9499-15]

Visualization approaches for displaying measures of sentiment, Sue E. Kase, Heather E. Roy, Daniel N. Cassenti, U.S. Army Research Lab. (USA) . . . . [9499-16]

Conversational sensemaking, Alun D. Preece, Cardiff Univ. (United Kingdom); Dave Braines, IBM United Kingdom Ltd. (United Kingdom); William Webberley, Cardiff Univ. (United Kingdom) . . . . [9499-17]

Collaborative human-machine analysis using a controlled natural language, David Mott, IBM United Kingdom Ltd. (United Kingdom); Donald R. Shemanski, The Pennsylvania State Univ. (USA); Cheryl A. Giammanco, U.S. Army Research Lab. (USA); Dave Braines, IBM United Kingdom Ltd. (United Kingdom) [9499-18]

Enhancing decision-making by leveraging human intervention in large-scale sensor networks, Enrico Casini, Florida Institute for Human & Machine Cognition (USA); Jessica Depree, Modus Operandi, Inc. (USA); Niranjan Suri, Florida Institute for Human & Machine Cognition (USA) and U.S. Army Research Lab. (USA); Jeffrey M. Bradshaw, Florida Institute for Human & Machine Cognition (USA); Teresa Nieten, Modus Operandi, Inc. (USA) . . . . [9499-19]

Lunch Break and Exhibition Time . . . . Tue 12:00 pm to 1:20 pm

CONFERENCE 9499

SESSION 5 . . . . .TUE 1:20 PM TO 3:00 PM

Advance Concepts II

Session Chair: **James Llinas,** Univ. at Buffalo (USA)

One decade of the DFIG model, Erik Blasch, Air Force Research Lab. (USA) . . . . [9499-20]

Combining human and machine processes (CHAMP), Moises Sudit, Univ. at Buffalo (USA); Michael Hirsch, Stetson Univ. (USA); David Sudit, BAE Systems (USA) . . . . [9499-21]

Composable systems, James Llinas, Univ. at Buffalo (USA); Kevin Barry, Lockheed Martin Corp. (USA) . . . . [9499-22]

Generalist analysts' at the edge and distributed analytics, Gavin Pearson, Bob Madahar, Defence Science and Technology Lab. (United Kingdom) . . . . [9499-23]

Argumentation and fusion of soft-hard information for threat prediction, Galina L. Rogova, Univ. at Buffalo (USA); Ronald R. Yager, Iona College (USA) . . . . [9499-24]

PANEL DISCUSSION . . . . 3:30 PM TO 5:00 PM

Next Generation Analytics Panel of Experts Discussion

Moderator: Barbara D. Broome, U.S. Army Research Lab. (USA)

INTERACTIVE POSTER SESSION
TUESDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Dealing with extreme data diversity: extraction and fusion from the growing types of document formats, Peter David, Nichole Hansen, James J. Nolan, Decisive Analytics Corp. (USA) . . . . [9499-25]

Towards an automated intelligence product generation capability, Timothy W. Hawes, Alison M. Smith, James J. Nolan, Decisive Analytics Corp. (USA) . . . . [9499-26]

Entity resolution using cloud computing, Alex James, CUBRC (USA) . . . . [9499-27]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9500

Wednesday–Friday 22–24 April 2015 • Proceedings of SPIE Vol. 9500

Quantum Information and Computation XIII

Conference Chairs: **Eric Donkor,** Univ. of Connecticut (USA); **Andrew R. Pirich,** ACP Consulting (USA); **Michael Hayduk,** Air Force Research Lab. (USA)

Conference Co-Chairs: **Michael R. Frey,** Bucknell Univ. (USA); **Samuel J. Lomonaco Jr.,** Univ. of Maryland, Baltimore County (USA); **John M. Myers,** Harvard Univ. (USA)

Program Committee: **Paul M. Alsing,** Air Force Research Lab. (USA); **Chip Brig Elliott,** Raytheon BBN Technologies (USA); **Reinhard K. Erdmann,** Advanced Automation Corp. (USA); **Michael L. Fanto,** Air Force Research Lab. (USA); **Louis H. Kauffman,** Univ. of Illinois at Chicago (USA); **Vladimir E. Korepin,** Stony Brook Univ. (USA); **Alexander V. Sergienko,** Boston Univ. (USA); **Tai Tsun Wu,** Harvard Univ. (USA)

WEDNESDAY 22 APRIL

SESSION 1. . . . . WED 1:00 PM TO 4:40 PM

QKD and Quantum Cryptography

Session Chairs: **Michael J. Hayduk,** Air Force Research Lab. (USA); **Michael L. Fanto,** Air Force Research Lab. (USA)

Towards secure networks using entangled photons and spins *(Invited Paper)*, Dirk R. Englund, Edward H. Chen, Tim Schroeder, Luozhou Li, Catherine Lee, Jacob C. Mower, Massachusetts Institute of Technology (USA) . . . [9500-1]

Performance limits for single-photons, correlated-photons, and entangled-photons for quantum key distribution over fiber optics network topologies, Eric Donkor, Fahad A. Althowibi, Ryan Williams, Univ. of Connecticut (USA) . . . . [9500-2]

A quadnat continuous-variable quantum key distribution using collated photons, Eric Donkor, Univ. of Connecticut (USA); Reinhard Erdmann, Advanced Automation Corp. (USA); David H. Hughes, Air Force Research Lab. (USA); Patrick D. Kumavor, Univ. of Connecticut (USA) . . . . [9500-3]

Quantum teleportation for key-less cryptography, Abhishek Parakh, Univ. of Nebraska at Omaha (USA) . . . . [9500-4]

Implementing Diffie?Hellman key exchange using quantum EPR pairs, Sayonnha Mandal, Abhishek Parakh, Univ. of Nebraska at Omaha (USA) . . . . [9500-5]

Provably secure time distribution for the electric grid, Amos M. Smith, Warren P. Grice, Phil G. Evans, Teja Kuruganti, Miljko Bobrek, Rapheal C. Pooser, Pavel Lougovski, Bing Qi, Oak Ridge National Lab. (USA) . . . . . [9500-6]

A modified QSS algorithm for distributing two party secret keys, Amos M. Smith, Warren P. Grice, Phil G. Evans, Benjamin J. Lawrie, Oak Ridge National Lab. (USA); Matthieu Legré, id Quantique SA (Switzerland); Pavel Lougovski, William Ray, Bing Qi, Oak Ridge National Lab. (USA). . . . . [9500-7]

Analysis of the secrecy of the running key in quantum encryption channels using coherent states of light, Vladimir V. Nikulin, David H. Hughes, John Malowicki, Vijit Bedi, Binghamton Univ. (USA) . . . . [9500-8]

Multidimensional manifold extraction for multicarrier continuous-variable quantum key distribution, Laszlo Gyongyosi, Budapest Univ. of Technology and Economics (Hungary) and Hungarian Academy of Sciences (Hungary); Sandor Imre, Budapest Univ. of Technology and Economics (Hungary) . [9500-9]

SESSION 2 . . . . WED 4:40 PM TO 6:20 PM

Quantum Imaging and Sensing

Session Chairs: **Samuel J. Lomonaco Jr.,** Univ. of Maryland, Baltimore County (USA); **Reinhard Erdmann,** Advanced Automation Corp. (USA)

Compressive quantum sensing, John C. Howell, Univ. of Rochester (USA); Gregory A. Howland, Air Force Research Lab. (USA); Samuel Knarr, Daniel Lum, James Schneeloch, Univ. of Rochester (USA) . . . . [9500-10]

Multi-path time-delay detection and estimation using a quantum annealer, John J. Tran, Information Sciences Institute (USA); Kevin J. Scully, Darren L. Semmen, Walter E. Lillo, The Aerospace Corp. (USA); Robert F. Lucas, Information Sciences Institute (USA). . . . . [9500-11]

Complementary imaging with compressive sensing, Gregory A. Howland, Air Force Research Lab. (USA) and Univ. of Rochester (USA); John C. Howell, James Schneeloch, Daniel Lum, Univ. of Rochester (USA) . . . . [9500-12]

Sensors based on quantum hyper-entanglement: efficiency and performance in the presence of other photon sources, James F. Smith III, U.S. Naval Research Lab. (USA) . . . . [9500-13]

Finding analytical solution for mirror inverse gate operations in quantum systems with diagonal interactions, Rudrayya C. Garigipati, Preethika Kumar, Wichita State Univ. (USA) . . . . [9500-14]

THURSDAY 23 APRIL

SESSION 3 . . . . .THU 8:00 AM TO 10:20 AM

Quantum Gates, Circuits, and Networks I

Session Chairs: **Eric Donkor,** Univ. of Connecticut (USA); **Samuel J. Lomonaco Jr.,** Univ. of Maryland, Baltimore County (USA)

Chip-scale quantum communications *(Invited Paper)*, Ryan M. Camacho, Paul S. Davids, Christopher T. DeRose, Mohan Sarovar, Junji Urayama, Sandia National Labs. (USA) . . . . [9500-15]

Quantum networks of trapped atomic ions *(Invited Paper)*, Christopher Monroe, Univ. of Maryland, College Park (USA) . . . . [9500-16]

Targeted single qubit gates with neutral atoms in a 3D optical lattice, David S. Weiss, Yang Wang, Aishwarya Kumar, The Pennsylvania State Univ. (USA) . . . . [9500-17]

Towards scalable quantum information processing with cold atoms and Rydberg blockade, Mark E. Saffman, Univ. of Wisconsin-Madison (USA) . . . . [9500-18]

Scalable quantum computing architecture with mixed species ion chains, Boris Blinov, John Wright, Tomasz Sakrejda, Richard Graham, Zichao Zhou, Carolyn Auchter, Thomas Noel, Univ. of Washington (USA). . . . . [9500-19]

High fidelity quantum information processing in surface ion traps, Jungsang Kim, Emily Mount, Daniel Gaultney, Stephen Crain, Geert Vrijsen, Duke Univ. (USA) . . . . [9500-20]

SESSION 4 . . . . .THU 10:50 AM TO 12:10 PM

Quantum Gates, Circuits and Networks II

Session Chairs: **Reinhard Erdmann,** Advanced Automation Corp. (USA); **John M. Myers,** Harvard Univ. (USA)

Superconducting metamaterials and qubits, Britton L. T. Plourde, Syracuse Univ. (USA) . . . . [9500-21]

An optimal fusion transformation for cluster state growth using only linear optical elements, Dmitry B. Uskov, Brescia Univ. (USA); Pavel Lougovski, Oak Ridge National Lab. (USA); Paul M. Alsing, Michael L. Fanto, Air Force Research Lab. (USA); Lev Kaplan, Tulane Univ. (USA); Amos M. Smith, Oak Ridge National Lab. (USA) . . . . [9500-22]

Functional role of tunneling in a programmable quantum annealer, Vadim N. Smelyanskiy, NASA Ames Research Ctr. (USA) . . . . [9500-23]

Induced dipole-dipole forbidden transitions in rare-earth elements and their prospects for quantum information processing, Eric Donkor, Ryan Williams, Fahad A. Althowibi, Univ. of Connecticut (USA). . . . . . . [9500-24]

Lunch Break and Exhibition Time . . . . Thu 12:10 pm to 1:40 pm

SESSION 5 . . . . THU 1:40 PM TO 3:20 PM

Quantum Measurements and Error Correction

Session Chairs: **Michael R. Frey,** Bucknell Univ. (USA); **Louis H. Kauffman,** Univ. of Illinois at Chicago (USA)

How often must we apply syndrome measurements?, Yaakov S. Weinstein, The MITRE Corp. (USA). . . . . [9500-25]

Random multipartite correlations measure pure multipartite entanglement, Minh C. Tran, Nanyang Technological Univ. (Singapore); Tomasz Paterek, Nanyang Technological Univ. (Singapore) and Ctr. for Quantum Technologies (Singapore); Wieslaw Laskowski, Univ. Gdanski (Poland); Francois Arnault, Univ. de Limoges (France); Borivoje Dakic, Vienna Ctr. for Quantum Science and Technology (Austria) and Univ. Wien (Austria) . . . . [9500-26]

Measuring arbitrarily accurate pulse compensation with randomized benchmarking, True Merrill, Georgia Tech Research Institute (USA); Chingiz Kabytayev, Georgia Institute of Technology (USA); Adam Meier, Georgia Tech Research Institute (USA); Kenneth R. Brown, Georgia Institute of Technology (USA) . . . . [9500-27]

Demonstrating continuous variable Einstein-Podolsky-Rosen steering with a finite number of measurements, James Schneeloch, Samuel Knarr, Gregory A. Howland, John C. Howell, Univ. of Rochester (USA) . . . . [9500-28]

Considerations on the collapse of the wave function, John F. Reintjes, Sotera Defense Solutions (USA); Mark Bashkansky, U.S. Naval Research Lab. (USA) . . . . [9500-29]

SESSION 6 . . . . THU 3:50 PM TO 6:10 PM

Quantum Information Science

Session Chairs: **Paul M. Alsing,** Air Force Research Lab. (USA); **Michael L. Fanto,** Air Force Research Lab. (USA)

Strong local passivity and system excitation energy, Michael R. Frey, Bucknell Univ. (USA) . . . . [9500-30]

Diagrammatic quantum mechanics, Louis H. Kauffman, Univ. of Illinois at Chicago (USA); Samuel J. Lomonaco Jr., Univ. of Maryland, Baltimore County (USA) . . . . [9500-31]

Fiber bundle approach to number scaling in physics and geometry, Paul Benioff, Argonne National Lab. (USA) . . . . [9500-32]

Consequences of recognizing unpredictability beyond quantum uncertainty, John M. Myers, Harvard Univ. (USA); Frederick H. Madjid, Consultant (USA) . . . . [9500-33]

Topological and geometrical quantum computation in cohesive homotopy type theory, Juan F. Ospina, Univ. EAFIT (Colombia) . . . . [9500-34]

Heterotic quantum and classical computing on a convergence space architecture, Howard A. Blair, Daniel R. Patten, Robert J. Irwin, David W. Jakel, Syracuse Univ. (USA) . . . . [9500-35]

Quantum probabilistic logic programming, Radhakrishnan Balu, U.S. Army Research Lab. (USA) . . . . [9500-36]

Theoretical analysis of on-chip linear quantum optical information processing networks, Stefan F. Preble, Jeffrey A. Steidle, Edwin E. Hach III, Rochester Institute of Technology (USA) . . . . [9500-37]

Geometric topological circuit diagrams for adiabatic quantum computation, Avishy Carmi, Ben-Gurion Univ. of the Negev (Israel); Daniel Moskovich, Tomasz Paterek, Nanyang Technological Univ. (Singapore)[9500-38]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

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Quantum random number generation algorithm realized by smartphone camera, Nan Wu, Kun Wang, Haixing Hu, Fangmin Song, Nanjing Univ. (China); Xiangdong Li, The City Univ. of New York (USA) . . . . [9500-49]

Absorption problems for three-state quantum walks, Kun Wang, Haixing Hu, Nan Wu, Fangmin Song, Nanjing Univ. (China); Xiangdong Li, The City Univ. of New York (USA). . . . . [9500-50]

FRIDAY 24 APRIL

SESSION 7 . . . . FRI 8:20 AM TO 10:00 AM

Quantum States and Quantum Entanglement I

Session Chairs: **John M. Myers,** Harvard Univ. (USA); **Paul M. Alsing,** Air Force Research Lab. (USA)

A bright PPKTP waveguide source of polarization entangled photons, Michael L. Fanto, Air Force Research Lab. (USA); Christopher C. Tison, Rome Research Corp. (USA) and Florida Atlantic Univ. (USA); Stefan F. Preble, Rochester Institute of Technology (USA); Paul M. Alsing, Air Force Research Lab. (USA) . . . . [9500-39]

High spectral purity silicon ring resonator photon-pair source, Stefan F. Preble, Rochester Institute of Technology (USA); Michael L. Fanto, Air Force Research Lab. (USA); Christopher C. Tison, Rome Research Corp. (USA) and Florida Atlantic Univ. (USA); Zihao Wang, Jeffrey A. Steidle, Rochester Institute of Technology (USA); Paul M. Alsing, Air Force Research Lab. (USA) . . [9500-40]

High heralding-efficiency of near-IR fiber coupled photon pairs for quantum technologies, P. Ben Dixon, Danna Rosenberg, Matthew E. Grein, MIT Lincoln Lab. (USA); Ryan S. Bennink, Oak Ridge National Lab. (USA); Veronika Stelmakh, Franco N. C. Wong, Massachusetts Institute of Technology (USA) . . . . [9500-41]

Parametric down conversion with a depleted pump and its relationship to the black hole information loss problem, Paul M. Alsing, Air Force Research Lab. (USA) . . . . [9500-42]

High-purity single-mode photon source for integrated quantum photonics, Xiyuan Lu, Wei C. Jiang, Jidong Zhang, Qiang Lin, Univ. of Rochester (USA) . . . . [9500-43]

SESSION 8 . . . . FRI 10:30 AM TO 11:50 AM

Quantum States and Quantum Entanglement II

Session Chairs: **Louis H. Kauffman,** Univ. of Illinois at Chicago (USA); **Michael R. Frey,** Bucknell Univ. (USA)

Coherently stimulated parametric down-conversion in quantum optical metrology, Christopher C. Gerry, Richard Birrittella, Anna Gura, Lehman College (USA) . . . . [9500-44]

Properties of antipodal atomic Schrödinger cat states, Christopher C. Gerry, Lehman College (USA); Edwin E. Hach III, Rochester Institute of Technology (USA) . . . . [9500-45]

States of photons with space-variant polarization, Enrique J. Galvez, Colgate Univ. (USA); Behzad Khajavi, Colgate Univ. (USA) and Florida Atlantic Univ. (USA); Xinru Cheng, Colgate Univ. (USA) and Univ. of Ottawa (Canada) [9500-46]

Entanglement as a mechanism for controlling distributed quantum systems, Samuel J. Lomonaco Jr., Univ. of Maryland, Baltimore County (USA); Louis H. Kauffman, Univ. of Illinois at Chicago (USA). . . . . [9500-47]

Superconducting circuitry for quantum electromechanical systems, Matthew LaHaye, Syracuse Univ. (USA) . . . . [9500-48]

CONFERENCE 9501

Thursday–Friday 23–24 April 2015 • Proceedings of SPIE Vol. 9501

Satellite Data Compression, Communications, and Processing XI

Conference Chairs: **Bormin Huang,** Univ. of Wisconsin-Madison (USA); **Chein-I Chang,** Univ. of Maryland, Baltimore County (USA)

Conference Co-Chairs: **Chulhee Lee,** Yonsei Univ. (Korea, Republic of); **Yunsong Li,** Xidian Univ. (China); **Qian Du,** Mississippi State Univ. (USA)

Program Committee: **Roberto Camarero,** Ctr. National d'Études Spatiales (France); **Lena Chang,** National Taiwan Ocean Univ. (Taiwan); **Yang-Lang Chang,** National Taipei Univ. of Technology (Taiwan); **Mitchell D. Goldberg,** National Oceanic and Atmospheric Administration (USA); **Allen H.-L. Huang,** Univ. of Wisconsin-Madison (USA); **Wenjiang Huang,** Institute of Remote Sensing and Digital Earth (China); **Roger L. King,** Mississippi State Univ. (USA); **José Fco. López,** Univ. de Las Palmas de Gran Canaria (Spain); **Sebastian López Suárez,** Univ. de Las Palmas de Gran Canaria (Spain); **Jarno Mielikainen,** Univ. of Eastern Finland (USA); **Daniela I. Moody,** Los Alamos National Lab. (USA); **Antonio J. Plaza,** Univ. de Extremadura (Spain); **Jordi Portell de Mora,** Institut d'Estudis Espacials de Catalunya (Spain); **Jeffery J. Puschell,** Raytheon Space & Airborne Systems (USA); **Shen-En Qian,** Canadian Space Agency (Canada); **Joan Serra-Sagrista,** Univ. Autònoma de Barcelona (Spain); **Xiaopeng Shao,** Xidian Univ. (China); **Meiping Song,** Dalian Maritime Univ. (China); **Carole Thiebaut,** Ctr. National d'Études Spatiales (France); **Behcet Ugur Töreyin,** Cankaya Univ. (Turkey); **Lifu Zhang,** Institute of Remote Sensing and Digital Earth (China)

THURSDAY 23 APRIL

SESSION 1. . . . . THU 8:30 AM TO 10:10 AM

Image Compression

Session Chair: **Bormin Huang,** Univ. of Wisconsin-Madison (USA)

Future CNES high-resolution remote sensing missions: novel image compression approaches for on-board processing units, Roberto Camarero, Carole Thiebaut, Christophe Latry, Mathieu Albinet, Jean-Marc Delvit, Ctr. National d'Études Spatiales (France) . . . . [9501-1]

Effects of compression on classification performance and discriminant information preservation in remotely sensed data, Chulhee Lee, Yonsei Univ. (Korea, Republic of); Jeoungyeol Baek, Yonsei Univ (Korea, Republic of); Sungwook Youn, Yonsei Univ. (Korea, Republic of) . . . . [9501-2]

Hyperspectral image compression using an online learning method, Behcet U. Töreyin, Irem Ulku, Cankaya Univ. (Turkey) . . . . [9501-3]

A novel compression for hyperspectral images based on invariant set multi-wavelets, Yongjun Li, Yunsong Li, Xidian Univ. (China) . . . . [9501-4]

FPGA based JPEG-LS encoder for onboard real-time lossless image compression, Yakup Murat Mert, TÜBİTAK BİLGEM İLTAREN (Turkey) [9501-5]

SESSION 2 . . . . THU 10:40 AM TO 12:00 PM

Image Processing I

Session Chair: **Chein-I Chang,** Univ. of Maryland, Baltimore County (USA)

Simplex volume analysis for finding endmembers in hyperspectral imagery, Hsiao-Chi Li, Univ. of Maryland, Baltimore County (USA); Meiping Song, Dalian Maritime Univ. (China); Chein-I Chang, Univ. of Maryland, Baltimore County (USA) . . . . [9501-6]

Super resolution imaging in remote sensing, Qiuhua Luo, Xiaopeng Shao, Lin Wang, Ligen Peng, Yi Wang, Xidian Univ. (China) . . . . [9501-7]

Hyperspectral image classification with a universal extreme learning machine, Qian Du, Mississippi State Univ. (USA); Wei Li, Beijing Univ. of Chemical Technology (China) . . . . [9501-8]

GSM-MR compression algorithm with two step sorting based on similarity analysis, Fei Cheng, Kai Liu, Jin Zhang, Wenwen Ding, Yunsong Li, Xidian Univ. (China) . . . . [9501-9]

Lunch Break and Exhibition Time . . . . Thu 12:00 pm to 1:30 pm

SESSION 3 . . . . THU 1:30 PM TO 3:10 PM

Image Processing II

Session Chair: **Chulhee Lee,** Yonsei Univ. (Korea, Republic of)

Pesticide residue quantification analysis by hyperspectral imaging sensors, Chein-I Chang, Univ. of Maryland, Baltimore County (USA); Yuan-Hsun Liao, Providence Univ. (Taiwan); Wei-Sheng Lo, Horng-Yuh Guo, Ching-Hua Kao, Tau-Meu Chou, Junne-Jih Chen, Taiwan Agricultural Research Institute Council of Agriculture, Executive Yuan (Taiwan); Chia-Hsien Wen, Providence Univ. (Taiwan); Chinsu Lin, National Chiayi Univ. (Taiwan); Hsian-Min Chen, Taichung Veterans General Hospital (Taiwan); Yen-Chieh Ouyang, National Chung Hsing Univ. (Taiwan); Chao-Cheng Wu, National Taipei Univ. of Technology (Taiwan); Shih-Yu Chen, National Yunlin Univ. of Science and Technology (Taiwan) . . . . [9501-10]

Adaptive sparse signal processing for discrimination of satellite-based radiofrequency (RF) recordings of lightning events, Daniela I. Moody, David A. Smith, Los Alamos National Lab. (USA) . . . . [9501-11]

An automatic fractional coefficient setting method of FODPSO for hyperspectral image segmentation, Weiying Xie, Yunsong Li, Xidian Univ. (China) . . . . [9501-12]

Optimizing the updated Goddard shortwave radiation weather research and forecasting (WRF) scheme for Intel many integrated core (MIC) architecture, Jarno Mielikainen, Bormin Huang, Hung-Lung A. Huang, Univ. of Wisconsin-Madison (USA). . . . . [9501-13]

Progressive band processing of orthogonal subspace projection in hyperspectral imagery, Hsiao-Chi Li, Yao Li, Cheng Gao, Univ. of Maryland, Baltimore County (USA); Meiping Song, Dalian Maritime Univ. (China); Chein-I Chang, Univ. of Maryland, Baltimore County (USA) . . . . [9501-14]

SESSION 4 . . . . THU 3:40 PM TO 5:40 PM

Image Processing III

Session Chair: **Yunsong Li,** Xidian Univ. (China)

Orthogonal projection based fully constrained spectral unmixing, Meiping Song, Dalian Maritime Univ. (China); Hsiao-Chi Li, Yao Li, Cheng Gao, Chein-I Chang, Univ. of Maryland, Baltimore County (USA) . . . . [9501-15]

Optical design for computing super-resolution imaging, Xiaopeng Shao, Jiaoyang Wang, Jie Xu, Xiaodong Chen, Xidian Univ. (China) . . . . [9501-16]

A multiple constrained signal subspace projection for target detection in hyperspectral images, Lena Chang, National Taiwan Ocean Univ. (Taiwan) . . . . [9501-17]

PCNN-based level set method of automatic mammographic image segmentation, Weiying Xie, Yunsong Li, Xidian Univ. (China) . . . . [9501-18]

Parallel implementation of WRF double moment 5-class cloud microphysics scheme on multiple GPUs, Melin Huang, Bormin Huang, Hung-Lung A. Huang, Univ. of Wisconsin-Madison (USA) . . . . [9501-19]

Richardson-Lucy deblurring for the star scene under a thinning motion path, Laili Su, Xiaopeng Shao, Lin Wang, Haixin Wang, Xidian Univ. (China) . . . . [9501-20]

CONFERENCE 9501

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

A novel super resolution camera mode00l, Xiaopeng Shao, Yi Wang, Jie Xu, Lin Wang, Fei Liu, Qiuhua Luo, Xiaodong Chen, Xidian Univ. (China) . . [9501-37]

Research on IR thermal emission polarization characteristics of smooth surface material, Fei Liu, Xiaopeng Shao, Bin Xiangli, Lin Wang, Ying Gao, Xidian Univ. (China) . . . . [9501-38]

A simulation method for analyzing infrared polarization scenes, Ying Gao, Xiaopeng Shao, Lin Wang, Fei Liu, Xidian Univ. (China) . . . . [9501-39]

A study of lighting detection and exposure algorithms for smart phones, Haixin Wang, Xiaopeng Shao, Lin Wang, Peng Gao, Laili Su, Xidian Univ. (China) . . . . [9501-40]

Blind image noise assessment based on local phase coherence, Lin Wang, Xiao Li, Xueyan Shi, Xiaopeng Shao, Yanyun Zhang, Xidian Univ. (China) . . . . [9501-41]

Research of ghost imaging with spatial light modulator, Xiaopeng Shao, Yang Zhang, Xue'en Wang, Lin Wang, Xidian Univ. (China) . . . . [9501-42]

A proof-concept optical design with super-resolution reconstruction, Xiaopeng Shao, Jie Xu, Jiaoyang Wang, Xiaodong Chen, Xidian Univ. (China) . . . . [9501-43]

Airborne experiment results for spaceborne atmospheric synchronous correction system, Wenyu Cui, Weining Yi, Lili Du, Xiao Liu, Anhui Institute of Optics and Fine Mechanics (China). . . . . [9501-51]

FRIDAY 24 APRIL

SESSION 5 . . . . FRI 8:00 AM TO 10:00 AM

Image Processing IV

Session Chair: **Qian Du,** Mississippi State Univ. (USA)

Finding endmember classes in hyperspectral imagery, Cheng Gao, Yao Li, Chein-I Chang, Univ. of Maryland, Baltimore County (USA). . . . [9501-21]

Skeleton-based action recognition using multiple sequence alignment, Wenwen Ding, Kai Liu, Fei Cheng, Jin Zhang, Yunsong Li, Xidian Univ. (China) . . . . [9501-22]

Support vector machine with adaptive composite kernel for hyperspectral image classification, Wei Li, Beijing Univ. of Chemical Technology (China); Qian Du, Mississippi State Univ. (USA) . . . . [9501-23]

Construction of WRF Stony Brook University 5-class scheme on Intel many integrated cores (MICs), Melin Huang, Bormin Huang, Hung-Lung A. Huang, Univ. of Wisconsin-Madison (USA) . . . . [9501-24]

Semi-supervised hyperspectral unmixing approach based nonnegative matrix factorization, Lifu Zhang, Taixia Wu, Nan Wang, Xia Zhang, Institute of Remote Sensing and Digital Earth (China) . . . . [9501-25]

Virtual dimensionality analysis for hyperspectral imagery, Drew Paylor, Li-Chien Lee, Chein-I Chang, Univ. of Maryland, Baltimore County (USA) . . . . [9501-26]

SESSION 6 . . . . FRI 10:30 AM TO 11:50 AM

Image Processing V

Session Chair: **Lifu Zhang,** Institute of Remote Sensing and Digital Earth (China)

A new detection algorithm for microcalcification clusters in mammographic screening, Weiying Xie, Yunsong Li, Xidian Univ. (China) . . . . [9501-27]

Adaptive nearest feature space approach to remote sensing image classification, Yang-Lang Chang, Min-Yu Huang, Zhen-Xian Wu, Jyh-Perng Fang, National Taipei Univ. of Technology (Taiwan); Lena Chang, National Taiwan Ocean Univ. (Taiwan) . . . . [9501-28]

Progressive band processing of pixel purity index for finding endmembers in hyperspectral imagery, Yao Li, Cheng Gao, Hsiao-Chi Li, Univ. of Maryland, Baltimore County (USA); Meiping Song, Dalian Maritime Univ. (China); Chein-I Chang, Univ. of Maryland, Baltimore County (USA) . . . . [9501-29]

Collaborative representation for hyperspectral image classification, Wei Li, Beijng Univ. of Chemical Technology (China); Qian Du, Mississippi State Univ. (USA) . . . . [9501-30]

Lunch Break . . . . Fri 11:50 am to 1:20 pm

SESSION 7 . . . . FRI 1:20 PM TO 3:20 PM

Image Processing VI

Session Chair: **Daniela I. Moody,** Los Alamos National Lab. (USA)

A vegetation classification method based on optimization of feature band set using hyperspectral remote sensing data, Xia Zhang, Lifu Zhang, Kun Shang, Yanli Sun, Institute of Remote Sensing and Digital Earth (China) . . . . [9501-31]

Accurate estimation of motion blur parameters in noisy remote sensing image, Xueyan Shi, Lin Wang, Xiao Li, Xiaopeng Shao, Hailing Bai, Xidian Univ. (China) . . . . [9501-32]

Further optimization of dynamics code of the advanced research weather research and forecasting (ARW) model for Intel Xeon Phi, Jarno Mielikainen, Bormin Huang, Hung-Lung A. Huang, Univ. of Wisconsin-Madison (USA) . . . . [9501-33]

A super resolution algorithm for degraded satellite image, Ligen Peng, Xiaopeng Shao, Lin Wang, Xiaodong Chen, Xidian Univ. (China). . . . . . [9501-34]

Hyperspectral vital sign signal analysis for medical data, Cheng Gao, Yao Li, Hsiao-Chi Li, Chein-I Chang, Univ. of Maryland, Baltimore County (USA); Peter F. Hu, Colin Mackenzie, Univ. of Maryland School of Medicine (USA) . . [9501-35]

Dehazing method through polarimetric imaging and multi-scale analysis, Lei Cao, Xiaopeng Shao, Fei Liu, Lin Wang, Xidian Univ. (China). . . . . . [9501-36]

Fiber Optic Sensors Program

This track highlights papers from both Defense + Security and Sensing Technology + Applications that showcase the latest in fiber optic sensors.

FIBER OPTIC SENSOR COURSES

Fundamentals of Fiber Optic Sensor Design and Technology

SC1160

Instructors: Eric Udd / Robert Lieberman
Schedule: Tuesday 21 April, 8:30 am - 5:30 pm
Price: $545 members / $640 non-members

Price includes the text *Fiber Optic Sensor Field Guide* (SPIE Press, 2015), by William B. Spillman and Eric Udd.

FIBER OPTIC SENSOR PRESENTATIONS

View the Fiber Optic Sensors and Applications XII conference (Conf. 9480) program at www.spie.org/st101 or see page 20.

(FOLLOWING PAPERS ORDERED NUMERICALLY BY CONFERENCE PAPER NUMBER)

A miniature fiber-optic sensor for high-resolution and high-speed temperature and flow sensing in ocean environment

PAPER 9459-19

Author(s): **Ming Han,** Univ. of Nebraska-Lincoln (USA), et al.
Conference 9459: Ocean Sensing and Monitoring VII
SESSION 4: Underwater Optical Imaging and Ranging II

In oceanography, the underwater thermal structures are critical for analyzing the energy events, monitoring material transfer, transmitting optical signals, etc. In this paper, we present an optical fiber sensor consisting of a thin piece of silicon wafer which forms a Fabry-Perot interferometer for the high-resolution and high-speed temperature profiling. A new data processing method has also been developed to reduce the signal-to-noise ratio of the system. Experimental results indicate that the fiber-optic temperature sensor can achieve a temperature resolution ~0.001 degree Celsius with a sampling frequency higher than 500 Hz. The ability of the sensor used as a water flow probe will also be demonstrated.

OEM fiber laser rangefinder for long-distance measurement

PAPER 9465-5

Author(s): **Alexandre Corman,** SensUp (France), et al.
Conference 9465A: Laser Radar Technology and Applications XX
SESSION 1: LIDAR Design/Demonstrations

SensUp designs, manufactures and commercializes OEM electro-optical systems based on laser technology. This presentation is focused on the development of the first OEM rangefinder based on fiber laser technology. The flexibility provided by this laser source coupled with the important peak power of solid-state lasers and the huge repetition rate of laser diodes, enable us to fit the SWAP requirements of the optronic market integrators. It actually turns out to be a real alternative to other technologies usually used in range finding systems.

Functional sensor material enabled harsh environment, high temperature optical sensors for energy applications

PAPER 9467-53

Author(s): **Paul R. Ohodnicki,** National Energy Technology Lab. (USA), et al.
Conference 9467: Micro- and Nanotechnology Sensors, Systems, and Applications VII
SESSION 10: Novel Harsh Environment Sensors for Energy Applications: Joint Session with Conferences 9467 and 9491

Opportunities exist for increasing efficiency and enabling new technology development in fossil-based power generation systems through embedded sensing at the highest value locations. Functional sensor materials can play an important role in enabling new sensor devices with unique functionality and improved stability. The in-house research team at the NETL has established an advanced sensor material program focused on research and development of sensing materials in parallel with demonstration on fabricated sensors under relevant conditions. A brief overview of the program and research team capabilities will be presented followed by recent breakthroughs of the on-going research and development efforts.

Ultra-high temperature fiber optical chemical sensors based on nano-porous metal oxides

PAPER 9467-54

Author(s): **Kevin P. Chen,** Univ. of Pittsburgh (USA), et al.
Conference 9467: Micro- and Nanotechnology Sensors, Systems, and Applications VII
SESSION 10: Novel Harsh Environment Sensors for Energy Applications: Joint Session with Conferences 9467 and 9491

This paper presents fiber optical gas sensors based on nano-porous metal oxide functional materials for high-temperature energy applications. A solution-based approach was used to produce nano-porous functional metal oxide and their dopant variants as sensing films, which was integrated on high-temperature stable FBGs in D-shaped silica fibers and sapphire fibers. The Bragg grating peaks were used to monitor the refractive index change and optical absorption loss due to the redox reaction between Pd-doped TiO_2 and hydrogen from the room temperature to 800C. The experimental results show the sensor's response is reversible for hydrogen concentration between 0.1 vol.% to 5 vol. %. The response time of the hydrogen sensor is <8s.

Phosphor-based fiber optic temperature sensors for harsh environments

PAPER 9467-55

Author(s): Nicholas Djeu, MicroMaterials, Inc. (USA), et al.
Conference 9467: Micro- and Nanotechnology Sensors, Systems, and Applications VII
SESSION 10: Novel Harsh Environment Sensors for Energy Applications: Joint Session with Conferences 9467 and 9491

Fiber optic temperature sensors based on Yb doped phosphors will be described. Two designs for the thermal probe have been successfully demonstrated. In the first design, the phosphor is a doped YAG in single crystal form and is grown directly onto one end of an undoped single crystal YAG fiber. When excited by a moderate-power diode laser, it can be operated up to 1,600 C. In the second approach, the phosphor is in the form of a doped ceramic YAG microsphere, butted against a silica fiber. With this design, operating temperatures up to 1,100 C can be reached using an LED.

LandSafe precision flight instrumentation system for rotorcraft operations in degraded environments

PAPER 9471-5

Author(s): **Pri Mamidipudi,** Optical Air Data Systems, LLC (USA), et al.
Conference 9471: Degraded Visual Environments: Enhanced, Synthetic, and External Vision Solutions 2015
SESSION 1: DVE Sensors I

Helicopter hover, landing, and take-off operations in darkness, dust, fog, rain, snow, and high winds is an integral part of military and commercial flight operations. OADS has developed and flight-tested a standalone LDV-based optical sensor suite capable of precisely measuring and reporting height above ground, groundspeed, ground drift, and air data at an FCS capable data rate from a helicopter platform under all environmental conditions. Details about the sensor and recent flight test results from multiple platforms will be presented.

A plastic optical fiber biosensor for e. coli

PAPER 9486-29

Author(s): **Domingos M. C. Rodrigues,** Univ. Federal of Rio de Janeiro (Brazil), et al.
Conference 9486: Advanced Environmental, Chemical, and Biological Sensing Technologies XII
TUESDAY POSTER SESSION: Interactive Poster Session: Tuesday Evening

This work presents a plastic optic fiber biosensor to detect Escherichia coli. Different probe shapes were tested: U-shaped with different radiuses, coil-shaped and meander-shaped. In calibration, we used solutions of sucrose for obtaining refractive indexes in the range 1.33 – 1.39 equivalent to water and bacteria, respectively. The setup consists of a LED connected to the probe and driven by microcontroller. In the opposite fiber end, the light received by a photodiode is amplified, and the output voltage varies accordingly to the captured bacteria. Measurement results for concentration readings of 104 CFU/mL are obtained in less than 10 minutes.

Light-directed functionalization methods for high-resolution optical fiber based biosensors

PAPER 9486-5

Author(s): Leyla N. Kahyaoglu, Purdue Univ. (USA), et al.
Conference 9486: Advanced Environmental, Chemical, and Biological Sensing Technologies XII
SESSION 2: Biosensors II

Implementation of a novel fiber-optic Fourier transform infrared (FO-FTIR) spectroscopy approach for non-contact and label-free sensing of biochemical contamination

PAPER 9487-12

Author(s): **Moinuddin Hassan,** U.S. Food and Drug Administration (USA), et al.
Conference 9487: Smart Biomedical and Physiological Sensor Technology XII
SESSION 3: Regulation and Monitoring

Healthcare associated infections (HAI) in clinics and hospitals are a major concern to public safety. Reusable medical devices can serve as a reservoir of infectious agents as they repeatedly come into contact with multiple patients and healthcare professionals. In order to reduce HAIs from reusable devices, alternative methods for quantitative, accurate, easy-to-use and real-time detection and identification of microorganism contaminations on medical devices surfaces in clinical setting are needed. We have developed a fiber-optic Fourier transform infrared (FO-FTIR) spectroscopy based sensing platform for non-contact, label-free and real-time detection of pathogens such as E.coli, S.aureus etc. on medical device surfaces.

Potential of commercial single-mode optical fibers as distributed sensors for high temperature measurement with PPP-BOTDA

PAPER 9491-10

Author(s): **Yi Bao,** Missouri Univ. of Science and Technology (USA), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 3: Optical Sensing Technology for Harsh Environments I

A commercial single-mode optical fiber is used as a distributed sensor to measure temperatures up to 1000ºC. The optical fiber was protected by a heat resistant glass tube with inside and outside diameters of 4 mm and 8 mm, respectively. The glass tube was heated at a thermal gradient of 8°C/min until 1000°C, and then was monotonously cooled to room temperature (22°C) in a thermostatic chamber. The distribution of Brillouin frequency shifts along each fiber were measured by a Neubrescope (Model NBX-7020) at different temperatures with pulse pre-pump Brillouin optical time domain analysis (PPP-BOTDA). The accuracy of temperature measurement is ±2°C. The measurement repeatability and spatial resolution are ±1°C and 4 cm, respectively.

Optical fiber distributed temperature and distributed acoustic sensing for remote and harsh environments

PAPER 9491-13

Author(s): **Michael Mondanos,** Silixa Ltd. (United Kingdom), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 4: Optical Sensing Technology for Harsh Environments II

Advances in opto-electronics and associated signal processing have enabled the development of optical fibre distributed acoustic and temperature sensors. Unlike systems relying on discrete optical sensors a distributed system does not rely upon manufactured sensors but utilises passive custom optical fibre cables resistant to harsh environments, including high temperature applications. These systems have been developed for the oil and gas industry to assist reservoir engineers in optimising the well lifetime. Nowadays these systems find a wide variety of applications as integrity monitoring tools .

Analysis of the coupling optical fiber ultrasonic sensor for partial discharges detection

PAPER 9491-15

Author(s): **Fengmei F. Li,** Xi'an Jiaotong Univ. (China), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 1: Novel Harsh Environment Sensors for Energy Applications: Joint Session with Conferences 9467 and 9491

Optical fiber reliability in subsea monitoring

PAPER 9491-16

Author(s): **Kaustubh Nagarkar,** GE Global Research (USA), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 4: Optical Sensing Technology for Harsh Environments II

Characterization and calibration of Raman based distributed temperature sensing system for 600C operation

PAPER 9491-8

Author(s): **Sudeep Mandal,** GE Global Research (USA), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 3: Optical Sensing Technology for Harsh Environments I

Fiber optic distributed temperature sensing based on Raman scattering of light in optical fibers has become a very attractive solution for distributed temperature sensing (DTS) applications. Currently, most Raman DTS instruments and fiber sensors are designed for operation up to approximately 300?C. We will present our work in demonstrating high temperature calibration of a Raman DTS system and describe the challenges of measuring large temperature ranges (0 – 600?C) with a single DTS interrogator. We will demonstrate the need to customize interrogator electronics and detector response in order to achieve reliable and repeatable high temperature measurements across a wide temperature range.

Coherent probe-pump-based Brillouin sensor for harsh environments

PAPER 9491-9

Author(s): **L. F. Zou,** OZ Optics Ltd. (Canada), et al.
Conference 9491: Sensors for Extreme Harsh Environments II
SESSION 3: Optical Sensing Technology for Harsh Environments I

A coherent probe-pump-based Brillouin sensor has been used for some harsh environments, such as leakage detection of oil and gas pipeline, monitoring of thunderstorms and rime ice on electricity power line, and monitoring of nuclear waste repository. The small leakage can be detected in five minutes after a leakage happened and the temperature change caused by the leakage increased with time during 15 minutes leakage operating. The effects of thunderstorms and rime ice on the power line were identified by monitoring strain on an OPGW with 140km optical fiber. The fiber types at high gamma doses that represent the harsh environment constraints associated with the considered application have been investigated by the coherent probe-pump-based Brillouin sensor.

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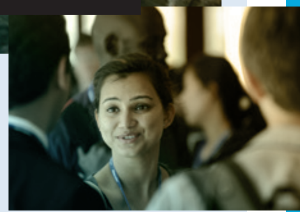

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We look forward to an even closer and stronger partnership with you during SPIE Defense + Security 2015.

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CONTENTS

GREEN PHOTONICS Cutting-edge developments in photonics-driven green technologies and applications. such as energy, sustainability, conservation, and environmental monitoring. Watch for this icon next to conferences discussing innovative ways to help our planet.

BEST PAPER AND BEST STUDENT PAPER AWARDS

The list of awards for the Defense + Security symposium may be updated as new awards are added.

Head- and Helmet-Mounted Displays XX: Design and Applications
(Conference 9470B)

Special emphasis will be placed on university research in general, and student conceived and executed research in particular. As an incentive, a non-monetary award for Best Student Paper will be given.

Display Technologies and Applications for Defense, Security, and Avionics IX
(Conference 9470A)

Each year, Best Paper Award is given based on originality, depth of research, significance of findings and/or historical interest. The award is based primarily on the oral presentation and is a joint decision stemming from input by conference committee members and chairs. The winner is determined shortly after the meeting, and notified by the conference chairs.

Signal Processing, Sensor/Information Fusion, and Target Recognition XXIV
(Conference 9474)

Commencing in 2015, a conference awards committee will be established to evaluate the submitted papers and associated presentation to select the Young Researcher Best Paper Award.

Algorithms for Synthetic Aperture Radar Imagery XXII
(Conference 9475)

In order to be considered for this award, the student must be the presenter and the primary author. A panel of experts will evaluate the papers, both for quality and content with regard to: 1) innovation, clarity, and style, and 2) the importance of the work to the field.

Automatic Target Recognition XXV
(Conference 9476)

ANNOUNCING THE 2015 ATR BEST PAPER AWARDS

Lockheed Martin Corporation has generously offered to sponsor the Best Paper Awards for the Automatic Target Recognition (ATR) conference, which will be held in Baltimore, Maryland, 20-24 May 2015. One or more in each category are planned: Best Student Paper Award and Best Paper Award.

In order to be considered for these awards:

- Presenter must make their oral presentation as scheduled
  Manuscript must be submitted to SPIE no later than the week of 23 March 2015.

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BEST STUDENT PAPER AWARDS

FOR STUDENTS: In addition to the above requirements, to be considered for the Best Student Paper Award:

- Student must be the presenting author at the conference
- Student must be the leading author of the manuscript
- Student must send a message to the conference chairs identifying them/you as a student. This should be done after you have submitted your abstract, and must include your Tracking Number and Paper Title.

Please send to:
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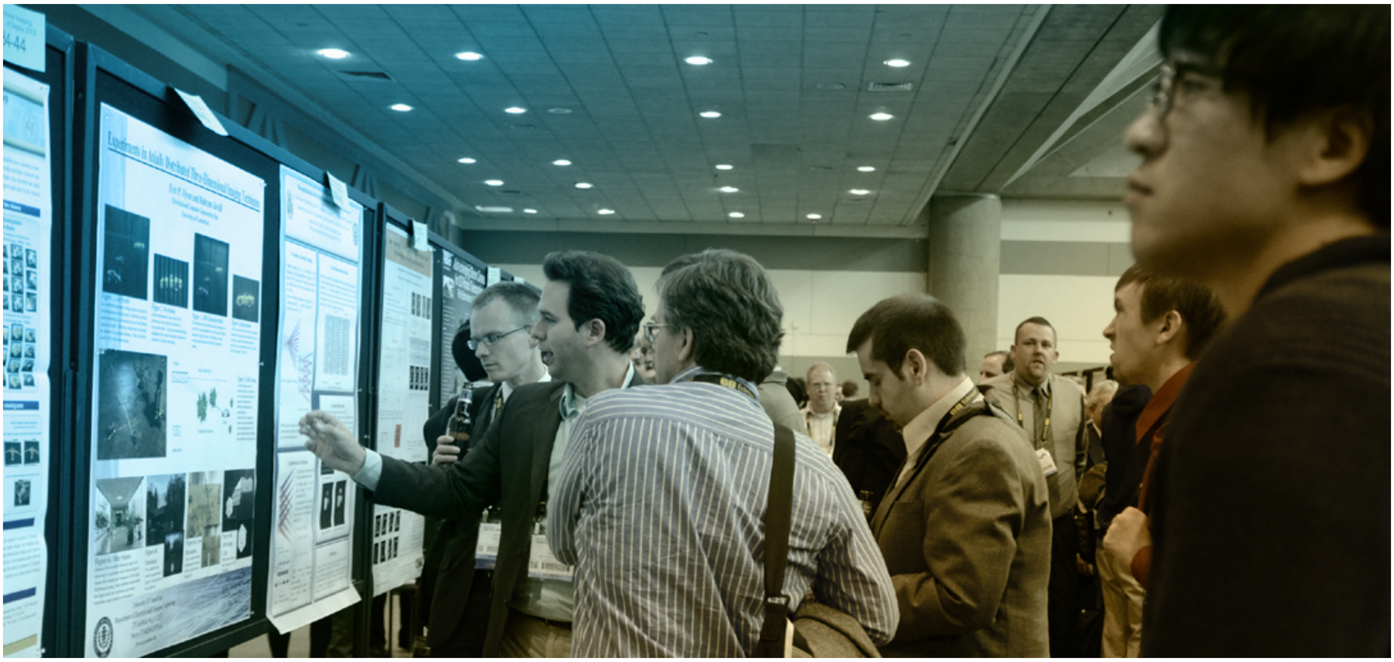
and
Abhijt Mahalanobis - abhijit.mahalanobis@lmco.com

A panel of experts headed by the ATR conference chairs will evaluate all the papers, both for quality and content. Attention will be given to 1) the innovation, clarity, and style of both the oral presentation at the conference and the manuscript submitted for publication, and 2) the importance of the work to the field of ATR. The winners will be recognized in person at the 2015 ATR conference. They will also be formally notified by email, and will receive a certificate of award.



AWARD ELIGIBILITY REQUIREMENTS FOR CONFERENCES:

Infrared Technology and Applications XLI (Conference 9451)

Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XVI (Conference 9455)

Micro- and Nanotechnology Sensors, Systems, and Applications VII (Conference 9467)

Geospatial Informatics, Fusion, and Motion Video Analytics V (Conference 9473)

CRITERIA FOR BEST PAPER AWARDS

In order to be considered for a Best Paper Award:

Presenter must make their oral or poster presentation as scheduled.

Manuscript must be submitted to the Proceedings of SPIE. The award decision is based on manuscript submission.

Please see the conference award description above and conference website to check for possible additional requirements.

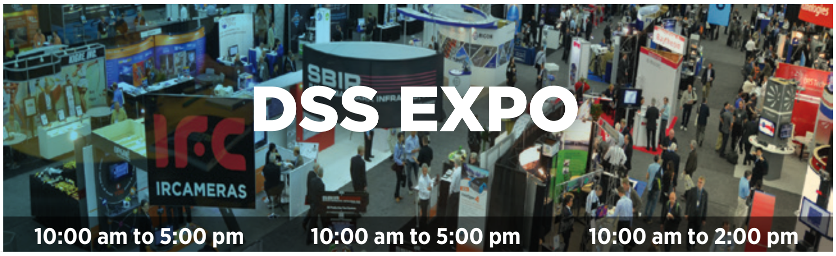
EVALUATION PROCESS

A panel coordinated by the Conference Chairs will evaluate all manuscripts submitted for consideration of high quality content. Attention may be given to 1) the innovation, clarity, and style of both the presentation at the conference and the manuscript submitted for publication, and 2) the importance of the work in the field.

Please contact your Conference Program Coordinator, Pat Wight, at patw@spie.org with any questions. Thank you for your interest!

DAILY CONFERENCE SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
DSS 2015 SYMPOSIUM PLENARY PRESENTATION Monday 20 April 2015 · 5:00 to 6:00 pm **Alan R. Shaffer,** Principal Deputy Assistant Secretary of Defense Research and Engineering, Department of Defense	DSS EXPO 10:00 am to 5:00 pm	DSS EXPO 10:00 am to 5:00 pm	DSS EXPO 10:00 am to 2:00 pm	
WELCOME RECEPTION, 6:15 to 7:45 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	**DEDICATED EXHIBITION TIME,** 10:00 am to 1:00 pm	**INTERACTIVE EVENING POSTER SESSION,** 6:00 to 7:30 pm	



IR Sensors and Systems

9451 **Infrared Technology and Applications XLI** (Andresen, Fulop, Hanson, Norton)

9452 **Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXVI** (Holst, Krapels)

9453 **Window and Dome Technologies and Materials XIV** (Zelinski)

Defense, Homeland Security, and Law Enforcement

9454 **Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XX** (Bishop, Issacs)

9455 **Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XVI** (Fountain)

9456 **Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security, Defense, and Law Enforcement Applications XIV** (Carapezza)

9458 **Cyber Sensing 2015** (Ternovskiy, Chin)

9457 **Biometric and Surveillance Technology for Human and Activity Identification XII** (Kakadiaris, Kumar, Scheirer)

9459 **Ocean Sensing and Monitoring VII** (Hou, Arnone)

Intelligence, Surveillance, and Reconnaissance

9460 **Airborne Intelligence, Surveillance, Reconnaissance (ISR) Systems and Applications XII** (Henry, Gosain, Lange, Linne von Berg, Walls, Young)

9462 **Passive and Active Millimeter-Wave Imaging XVIII** (Wikner, Luukanen)

9461A **Radar Sensor Technology XIX** (Ranney, Doerry)

9463 **Motion Imagery: Standards, Quality, and Interoperability** (Self)

9464 **Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR VI** (Pham, Kolodny)

Laser Sensors, and Systems

9465A **Laser Radar Technology and Applications XX** (Turner, Kamerman)

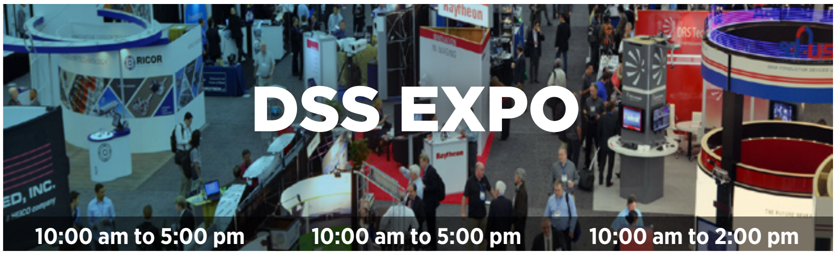
9465B **Atmospheric Propagation XII** (Wasiczko-Thomas, Spillar)

9466 **Laser Technology for Defense and Security XI** (Dubinskii, Post)

9461B **Active and Passive Signatures VI** (Gilbreath, Hawley)

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY

DSS 2015 SYMPOSIUM PLENARY PRESENTATION
Monday 20 April 2015 · 5:00 to 6:00 pm
Alan R. Shaffer, Principal Deputy Assistant Secretary of Defense Research and Engineering, Department of Defense



WELCOME RECEPTION, 6:15 to 7:45 pm

INTERACTIVE EVENING POSTER SESSION, 6:00 to 7:30 pm

DEDICATED EXHIBITION TIME, 10:00 am to 1:00 pm

INTERACTIVE EVENING POSTER SESSION, 6:00 to 7:30 pm

Next-Generation Sensors and Systems

9467 **Micro- and Nanotechnology Sensors, Systems, and Applications VII** (George, Dutta, Islam)

9468 **Unmanned Systems Technology XVII** (Karlsen, Gage, Shoemaker, Gerhart)

9469 **Sensors and Systems for Space Applications VIII** (Pham, Chen)

Displays

9470A **Display Technologies and Applications for Defense, Security, and Avionics IX** (Desjardins)

9471 **Degraded Visual Environments: Enhanced, Synthetic, and External Vision Solutions 2015** (Güell, Sanders-Reed)

9470B **Head- and Helmet-Mounted Displays XX: Design and Applications** (Marasco, Havig, Browne, Melzer)

Sensor Data and Information and Exploitation

9472 **Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XXI** (Velez-Reyes, Kruse)

9473 **Geospatial Informatics, Fusion, and Motion Video Analytics V** (Pellechia, Palaniappan, Dockstader, Seetharamen)

9475 **Algorithms for Synthetic Aperture Radar Imagery XXII** (Zelnio, Garber)

9474 **Signal Processing, Sensor/Information Fusion, and Target Recognition XXIV** (Kadar)

Imagery and Pattern Analysis

9476 **Automatic Target Recognition XXV** (Sadjadi, Mahalanobis)

9477 **Optical Pattern Recognition XXVI** (Casasent, Alam)

Information Systems and Networks: Processing, Fusion, and Knowledge Generation

9478 **Modeling and Simulation for Defense Systems and Applications X** (Kelmelis)

9479 **Open Architecture/Open Business Model Net-Centric Systems and Defense Transformation 2015** (Suresh)

CONFERENCE 9451

Monday–Thursday 20–23 April 2015 • Proceedings of SPIE Vol. 9451

Infrared Technology and Applications XLI

Conference Chairs: **Bjørn F. Andresen,** Consultant, IR Tech. and Appl. (Israel); **Gabor F. Fulop,** Maxtech International, Inc. (USA); **Charles M. Hanson,** SenseIR Solutions, LLC (USA); **Paul R. Norton,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Program Committee: **Tayfun Akin,** Mikro-Tasarim Ltd. (Turkey), Middle East Technical Univ. {Turkey); **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Stefan T. Baur,** Raytheon Vision Systems (USA); **Philippe F. Bois,** Thales Research & Technology (France); **Wolfgang A. Cabanski,** AIM INFRAROT-MODULE GmbH (Germany); **John T. Caulfield,** Cyan Systems (USA); **Eric M. Costard,** SOFRADIR (France); **Ronald G. Driggers,** St. Johns Optical Systems (USA); **Michael T. Eismann,** Air Force Research Lab. (USA); **Christy Fernandez-Cull,** MIT Lincoln Lab. (USA); **Mark E. Greiner,** L-3 Communications Cincinnati Electronics (USA); **Sarath D. Gunapala,** Jet Propulsion Lab. (USA); **Masafumi Kimata,** Ritsumeikan Univ. (Japan); **Hee Chul Lee,** KAIST (Korea, Republic of); **Paul D. LeVan,** Air Force Research Lab. (USA); **Chuan C. Li,** DRS Technologies, Inc. (USA); **Kevin C. Liddiard,** Electro-optic Sensor Design (Australia); **Wei Lu,** Shanghai Institute of Technical Physics (China); **Tara J. Martin,** UTC Aerospace Systems (USA); **Paul L. McCarley,** Air Force Research Lab. (USA); **R. Kennedy McEwen,** SELEX ES (United Kingdom); **John L. Miller,** FLIR Systems, Inc. (USA); **A. Fenner Milton,** U.S. Army RDECOM CERDEC NVESD (USA); **Mario O. Münzberg,** Airbus Defence and Space (Germany); **Peter W. Norton,** BAE Systems (USA); **Robert A. Owen,** L-3 Communications EOTech. (USA); **Joseph G. Pellegrino,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Donald A. Reago Jr.,** U.S. Army RDECOM CERDEC NVESD (USA); **Colin E. Reese,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Sergey V. Riabzev,** RICOR-Cryogenic & Vacuum Systems (Israel); **Patrick Robert,** ULIS (France); **Antoni Rogalski,** Military Univ. of Technology (Poland); **Ingo Rühlich,** AIM INFRAROT-MODULE GmbH (Germany); **Jas S. Sanghera,** U.S. Naval Research Lab. (USA); **Itay Shtrichman,** SCD Semiconductor Devices (Israel); **Rengarajan Sudharsanan,** Spectrolab, Inc., A Boeing Co. (USA); **Stefan P. Svensson,** U.S. Army Research Lab. (USA); **Alan Symmons,** LightPath Technologies, Inc. (USA); **J. Ralph Teague,** Georgia Tech Research Institute (USA); **Simon Thibault,** Univ. Laval (Canada); **Meimei Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Alexander Veprik,** SCD Semiconductor Devices (Israel); **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Michel Vuillermet,** SOFRADIR (France); **James R. Waterman,** U.S. Naval Research Lab. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

Monday 20 April

OPENING REMARKS . . . . 8:00 AM TO 8:10 AM

Gabor F. Fulop , Maxtech International, Inc. (USA)

SESSION 1. . . . . MON 8:10 AM TO 10:10 AM

NIR / SWIR FPAs and Applications

Session Chairs: **Mario O. Münzberg,** Airbus DS Optronics GmbH (Germany); **Eric M. Costard,** SOFRADIR (France)

Improved sensitivity performance of SWIR imager in a multispectral VIS/SWIR zoom camera for long-range surveillance tasks, Martin Huebner, Bertram Achtner, Michael Kraus, Mario O. Münzberg, Airbus DS Optronics GmbH (Germany). . . . . [9451-1]

Smart onboard image enhancement algorithms for SWIR day and night vision camera, Jo Das, Koen Vanhoof, Guy Gielis, Benedict Gouverneur, Pieter D. Deroo, Xenics NV (Belgium); Raf L. P. Vandersmissen, sInfraRed Pte. Ltd. (Singapore); Jan P. Vermeiren, Xenics NV (Belgium); Patrick J. Merken, Xenics NV (Belgium) and Royal Military Academy (Belgium) . . . . [9451-2]

Low-cost SWIR imaging: demonstration of a colloidal quantum dot focal plane array, Ethan J. D. Klem, Christopher W. Gregory, Dorota S. Temple, Jay S. Lewis, RTI International (USA) . . . . [9451-3]

InGaAs focal plane array developments and perspectives, Anne Rouvié, Jérôme Coussement, Odile Huet, Jean-Patrick Truffer, Maxime Pozzi, El-Houcine Oubensaid, Sébastien Hamard, Vincent Chaffraix, Eric M. Costard, SOFRADIR (France). . . . . [9451-4]

Low light level CMOS sensor for night vision camera, Elad Gross, Ran Ginat, Ofer Nesher, Elbit Systems Ltd (Israel) . . . . [9451-5]

IR CMOS: the digital nightvision solution to sub-1 mLux imaging, Martin U. Pralle, James E. Carey III, Chris J. Vineis, SiOnyx Inc. (USA) . . . . [9451-6]

SESSION 2 . . . . MON 10:40 AM TO 11:30 AM

Infrared in the Service of the Navy I

Session Chair: **James R. Waterman,** U.S. Naval Research Lab. (USA)

Semi-scanning single sensor omni-directional observation system *(Invited Paper)*, Yan Itovich, Dan V. Regelman, Rafael Advanced Defense Systems Ltd. (Israel) . . . . [9451-8]

Considerations for opto-mechanical versus digital stabilization in surveillance systems *(Invited Paper)*, David Kowal, CONTROP Precision Technologies Ltd. (Israel) . . . . [9451-9]

Lunch Break . . . . Mon 11:30 am to 1:00 pm

SESSION 3 . . . . MON 1:00 PM TO 1:40 PM

Infrared in the Service of the Navy II

Session Chair: **James R. Waterman,** U.S. Naval Research Lab. (USA)

Naval piracy acts: design of an infrared multiple cameras system for short-range detection and targeting *(Invited Paper)*, Dominique Maltese, Sagem Défense Sécurité (France) . . . . [9451-10]

TBD on naval system, ... [9451-11]

SESSION 4 . . . . MON 1:40 PM TO 3:00 PM

Infrared Imagers: Variations On a Theme

Session Chairs: **R. Kennedy McEwen,** SELEX ES (United Kingdom); **Torbjørn Skauli,** Norwegian Defence Research Establishment (Norway)

Future of clip-on weapon sights: pros and cons from an applications perspective, Glen L. Francisco, C. Reed Knight Jr., Ken Greenslade, Knight's Armament Co. (USA) . . . . [9451-12]

Development of an infrared ultra-compact multichannel camera integrated in a SOFRADIR's detector Dewar cooler assembly, Guillaume Druart, Florence de la Barrière, Nicolas Guérineau, Aurélien Plyer, ONERA (France); Gilles Lasfargues, Eric D. de Borniol, Commissariat à l'Énergie Atomique (France); Serge Magli, SOFRADIR (France). . . . . [9451-13]

Spin scan tomographic infrared imager, Harald Hovland, Norwegian Defence Research Establishment (Norway) . . . . [9451-14]

TBD on hyperspectral imager, ... [9451-15]

SESSION 5 . . . . .MON 3:30 PM TO 4:30 PM

Infrared Imaging: Retaining Acquisition

Session Chairs: **Torbjørn Skauli,** Norwegian Defence Research Establishment (Norway); **R. Kennedy McEwen,** SELEX ES (United Kingdom)

Minimising blooming in MWIR missile launch systems, Patrick R. Body, TECNOBIT (Spain). . . . . [9451-16]

Passive electro optical counter-countermeasures, Ariela Donval, Tali Fisher, Moshe Oron, KiloLambda Technologies, Ltd. (Israel) . . . . [9451-17]

Daylight coloring for monochrome infrared imagery, James Gabura, Raytheon ELCAN Optical Technologies (Canada) . . . . [9451-18]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 6 . . . . .TUE 8:00 AM TO 9:30 AM

Type II Superlattice FPAs I

Session Chairs: **Meimei Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

In/As/InAs$_{1-x}$Sb$_x$ type-II superlattices for high-performance long-wavelength infrared detection *(Invited Paper)*, Manijeh Razeghi, Abbas Haddadi, Guanxi A. Chen, R. Chevallier, Anh Minh Hoang, Northwestern Univ. (USA) . . . . [9451-19]

Type-II superlattice detector for long-wave infrared imaging *(Invited Paper)*, Philip C. Klipstein, Eran Avnon, Yael Benny, Avraham Fraenkel, Alex Glozman, Elad Ilan, Ezra Kahanov, Olga Klin, Lidia Langof, SCD SemiConductor Devices (Israel); Yoav Livneh, Israel Ministry of Defense (Israel); Inna Lukomsky, Michal Nitzani, Lior Shkedy, Itay Shtrichman, Noam Snapi, Ron Talmor, SCD SemiConductor Devices (Israel); Avi Tuito, IMOD (Israel); Shay Vaserman, Eliezer Weiss, SCD SemiConductor Devices (Israel) . . . . [9451-20]

InAs/Ga(In)Sb type-II superlattices short/middle dual-color infrared detectors *(Invited Paper)*, Yanli Shi, Kunming Institute of Physics (China) . . . . [9451-21]

SESSION 7 . . . . TUE 9:30 AM TO 10:00 AM

Keynote Session

Session Chair: **Paul R. Norton,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

TBD *(Keynote Presentation)*, Donald Reago, U.S. Army REDECOM CERDEC NVESD (USA) . . . . [9451-22]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Tuesday morning coffee break while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 8 . . . . TUE 1:00 PM TO 4:40 PM

Type II Superlattice FPAs II

Session Chairs: **Meimei Tidrow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Manijeh Razeghi,** Northwestern Univ. (USA); **Lucy Zheng,** Institute for Defense Analyses (USA)

High-performance bias-selectable dual-band mid-/long-wavelength infrared photodetectors based on InAs/InAs$_{1-x}$Sb$_x$ type-II superlattices *(Invited Paper)*, Manijeh Razeghi, Abbas Haddadi, R. Chevallier, Guanxi A. Chen, Anh Minh Hoang, Northwestern Univ. (USA). . . . . [9451-23]

Limiting dark current mechanisms in antimony-based superlattice infrared detectors for the mid- and long-wavelength infrared regime, Robert Rehm, Volker Daumer, Tsvetlina Hugger, Norbert Kohn, Florian Lemke, Wolfgang Luppold, Jasmin Niemasz, Johannes Schmidt, Johannes Schmitz, Frank Rutz, Tim O. Stadelmann, Matthias Wauro, Andreas Wörl, Martin Walther, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany). . . . . [9451-24]

Modeling of the InAs/GaSb superlattices performance, Julien Imbert, ONERA (France); Virginie Trinite, III-V Lab. (France); Sophie Derelle, Julien Jaeck, ONERA (France); Jean-Baptiste Rodriguez, Institut d'Electronique du Sud (France); Riad Haidar, ONERA (France); Mathieu Carras, III-V Lab. (France); Philippe Christol, Institut d'Electronique du Sud (France). . . . . [9451-25]

Carrier transport in unipolar barrier infrared detectors, David Z. Ting, Alexander Soibel, Linda Höglund, Cory J. Hill, Arezou Khoshakhlagh, Sam A. Keo, Anita M. Fisher, Layton Baker, Edward M. Luong, Robert S. Kowalczyk, John K. Liu, Jason M. Mumolo, Sir B. Rafol, Sarath D. Gunapala, Jet Propulsion Lab. (USA) . . . . [9451-26]

Minority carrier lifetimes in InAs/InAsSb type-II superlattices measured using double-modulation time-resolved photoluminescence, Zhiyuan Lin, Shi Liu, Yong-Hang Zhang, Arizona State Univ. (USA) . . . . [9451-27]

TBD *(Invited Paper)*, ... [9451-28]

Confocal Raman spectroscopy and AFM for evaluation of sidewalls in type-II superlattices, Alexander A. Ukhanov, Tito L. Busani, Pranav Rathi, Thomas J. Rotter, Felix Jaeckel, Kevin J. Malloy, Actoprobe LLC (USA); Elena Plis, Sanjay Krishna, SKINfrared LLC (USA); Neil F. Baril, J. D. Benson, Marvin Jaime-Vasquez, U.S. Army RDECOM CERDEC NVESD (USA); Dmitri A. Tenne, Boise State Univ. (USA). . . . . [9451-29]

Growth and characterization of ≥6" epitaxy-ready GaSb substrates for use in large-area infrared detector applications, Mark J. Furlong, IQE IR (United Kingdom); Rebecca J. Martinez, Marius Tybjerg, Andrew Mowbray, Brian Smith, Wafer Technology Ltd. (United Kingdom) . . . . [9451-30]

MBE growth of Sb-based bulk nBn infrared photodetector structures on ≥6" GaSb substrates, Amy W. K. Liu, Dmitri Loubychev, Yueming Qiu, Joel M. Fastenau, IQE Inc. (USA); Mark J. Furlong, IQE IR (United Kingdom); Marius Tybjerg, Wafer Technology Ltd. (United Kingdom); Rebecca J. Martinez, IQE IR (United Kingdom); Andrew Mowbray, Brian Smith, Wafer Technology Ltd. (United Kingdom). . . . . [9451-31]

SESSION 9 . . . . TUE 4:40 PM TO 5:40 PM

ROIC and NUC

Session Chairs: **Paul L. McCarley,** Air Force Research Lab. (USA); **John T. Caulfield,** Cyan Systems (USA)

Digital pixel readout integrated circuit architectures for LWIR, Melik Yazici, Huseyin Kayahan, Omer Ceylan, Atia Shafique, Yasar Gurbuz, Sabanci Univ. (Turkey) . . . . [9451-32]

A 1280×1024-15 µm CTIA ROIC for SWIR FPAs, Selim Eminoglu, MikroSens Elektronik San ve Tic A S (Turkey) . . . . [9451-33]

Cryogenic measurements of a digital pixel readout integrated circuit for LWIR, Atia Shafique, Melik Yazici, Huseyin Kayahan, Omer Ceylan, Yasar Gurbuz, Sabanci Univ. (Turkey). . . . . [9451-34]

INTERACTIVE POSTER SESSION
TUESDAY EVENING.................... 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Design of IR omni-directional optical system for night vision and surveillance of defence and safety *(Invited Paper)*, Jae Heung Jo, Hannam Univ. (Korea, Republic of); Jae Myung Ryu, Kumoh National Institute of Technology (Korea, Republic of); Jong-goo Kang, Hannam Univ. (Korea, Republic of) .... [9451-7]

Study on magnetic circuit of moving magnet linear compressor, Xia Ming, Xiaoping Chen, Xiaoping Chen, Kunming Institute of Physics (China) . . [9451-91]

Polarization-selective uncooled infrared sensor using a one-dimensional plasmonic grating absorber, Shinpei Ogawa, Mitsubishi Electric Corp. (Japan); Yousuke Takagawa, Masafumi Kimata, Ritsumeikan Univ. (Japan) . . . . [9451-92]

Model, design, and fabrication of antenna coupled metal-insulator-metal diodes for IR sensing, Mesut Inac, Atia Shafique, Yasar Gurbuz, Meriç Özcan, Sabanci Univ. (Turkey)...................................... [9451-93]

Low-power LVDS for digital readout circuits, Melik Yazici, Huseyin Kayahan, Omer Ceylan, Atia Shafique, Yasar Gurbuz, Sabanci Univ. (Turkey) . . . [9451-94]

A study of doping influences on transmission of large-diameter gallium antimonide substrates for long-wave (LWIR) to very long wavelength (VLWIR) infrared applications, Rebecca J. Martinez, IQE IR (United Kingdom); Andrew Mowbray, Brian Smith, Marius Tybjerg, Wafer Technology Ltd. (United Kingdom); Mark J. Furlong, IQE IR (United Kingdom)............... [9451-95]

A 640×480-17 µm ROIC for uncooled microbolometer FPAs, Selim Eminoglu, MikroSens Elektronik San ve Tic A S (Turkey) .... [9451-96]

SiO_2 films mask processed by lift-off techniques for plasma etching of HgCdTe, Yiyu Chen, Univ. of Chinese Academy of Sciences (China); Zhenhua Ye, Shanghai Institute of Technical Physics (China)................ [9451-97]

Thermal stability of atomic layer deposition Al_2O_3 film on HgCdTe, P. Zhang, Shanghai Institute of Technical Physics (China); Changhong Sun, Y. Zhang, Shanghai Institute of Technical Physics (China); X. Chen, Shanghai Institute of Technical Physics (China); Y. Y. Chen, Zhenhua Ye, Shanghai Institute of Technical Physics (China) .... [9451-98]

Preliminary validation results of an ASIC for the readout and control of near-infrared large array detectors, Philip Påhlsson, Dirk X. Meier, Hans Kristian Otnes Berge, Petter Øya, David Steenari, Alf Olsen, Amir Hasanbegovic, Mehmet Akif Altan, Bahram Najafiuchevler, Jahanzad Talebi, Suleyman Azman, Codin Gheorghe, Jörg Ackermann, Gunnar Mæhlum, Integrated Detector Electronics AS (Norway) .... [9451-99]

POSTERS/ORAL STANDBYS .... TUE 6:00 PM TO 7:30 PM

Survivability of Corning durable silver-based multispectral mirrors, Leonard G. Wamboldt, Corning Incorporated (USA)...................... [9451-101]

Wednesday 22 April

Session 10 runs concurrently with session 13.

SESSION 10 .... WED 8:00 AM TO 11:20 AM

HOT: High Operating Temperature FPAs

Session Chairs: **Michael T. Eismann,** Air Force Research Lab. (USA); **Philip C. Klipstein,** SCD SemiConductor Devices (Israel)

Infrared SWAP detectors: pushing the limits, Yann Reibel, Laurent Rubaldo, Rachid Taalat, Alexandre Kerlain, Nicolas Péré-Laperne, Marie-Lise Bourqui, David Billon-Lanfrey, SOFRADIR (France); Gérard Destéfanis, Olivier Gravrand, Pierre Castelein, CEA-LETI (France) .... [9451-35]

Firefly: A HOT camera core for thermal imagers with enhanced functionality, Luke Pillans, Tim Edwards, Lee Richardson, David Jeckells, SELEX ES (United Kingdom)................................. [9451-36]

Fabrication of high-operating temperature (HOT), MWIR transparent photon-trap barrier-based detectors, Hasan Sharifi, Mark S. Roebuck, James Jenkins, Sevag Terterian, Pierre-Yves Delaunay, Terrence J. De Lyon, Daniel Yap, Sarabjit Mehta, Rajesh D. Rajavel, HRL Labs., LLC (USA)....... [9451-37]

High-operating temperature MWIR unipolar barrier photodetectors based on strained layer superlattices, David A. Ramirez, Stephen A. Myers, Elena Plis, SKINfrared LLC (USA); Sanjay Krishna, SKINfrared LLC (USA) and The Univ. of New Mexico (USA)................................. [9451-38]

Effects of AlSb interfaces on InAs/InAsSb type-II infrared superlattice material properties, Elizabeth H. Steenbergen, Air Force Research Lab. (USA); Zhiyuan Lin, Arizona State Univ. (USA); Said Elhamri, Univ. of Dayton (USA); Yong-Hang Zhang, Arizona State Univ. (USA); Ron Kaspi, Air Force Research Lab. (USA) .... [9451-39]

Progress on the development of interband cascade photodetectors *(Invited Paper)*, Zhao-Bing Tian, Sanjay Krishna, The Univ. of New Mexico (USA)....... [9451-40]

Numerical analysis of CdS/PbSe room temperature mid-infrared heterojunction photovoltaic detectors, Binbin Weng, Jijun Qiu, Lihua Zhao, Zhisheng Shi, The Univ. of Oklahoma (USA)..................... [9451-41]

Long-wave infrared HgCdTe unipolar PBνn photodetector, Weida Hu, Shanghai Institute of Technical Physics (China) .... [9451-42]

Lunch/Exhibition Break.........................Wed 11:20 am to 1:30 pm

SESSION 13..................... WED 8:00 AM TO 10:10 AM

Chalcogenide Glasses in IR Optical Design

Session Chairs: **Jasbinder S. Sanghera,** U.S. Naval Research Lab. (USA); **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Design and high-volume manufacture of low-cost molded IR aspheres for personal thermal imaging devices, Amy L. Zelazny, Kenneth F. Walsh, John P. Deegan, Brian Bundschuh, Edward K. Patton, Rochester Precision Optics, LLC (USA) .... [9451-54]

Design and fabrication of multispectral optics using expanded glass map, Shyam S. Bayya, Daniel J. Gibson, Vinh Q. Nguyen, Jasbinder S. Sanghera, U.S. Naval Research Lab. (USA); Mikhail Kotov, Sotera Defense Solutions, Inc. (USA); Gryphon Drake, Univ. Research Foundation (USA); John P. Deegan, George P. Lindberg, Rochester Precision Optics, LLC (USA) .... [9451-55]

Investigation of As40Se60 chalcogenide glass in precision glass molding for high-volume thermal imaging lenses, Alan Symmons, Raymond J. Pini, William V. Moreshead, Jacklyn Novak, LightPath Technologies, Inc. (USA) .... [9451-56]

GRIN optics for multispectral infrared imaging *(Invited Paper)*, Daniel J. Gibson, Shyam S. Bayya, Jasbinder S. Sanghera, Vinh Q. Nguyen, U.S. Naval Research Lab. (USA); Mikhail Kotov, Sotera Defense Solutions, Inc. (USA); Gryphon Drake, Univ. Research Foundation (USA) .... [9451-57]

Index change of chalcogenide materials from precision glass molding processes, John P. Deegan, George P. Lindberg, Robert Benson, Rochester Precision Optics, LLC (USA); Daniel J. Gibson, Shyam S. Bayya, Jasbinder S. Sanghera, U.S. Naval Research Lab. (USA) .... [9451-58]

Methods of both destructive and non-destructive metrology of GRIN optical elements, George P. Lindberg, John P. Deegan, Robert Benson, Rochester Precision Optics, LLC (USA); Daniel J. Gibson, Shyam S. Bayya, Jasbinder S. Sanghera, Vinh Q. Nguyen, U.S. Naval Research Lab. (USA); Mikhail Kotov, Sotera Defense Solutions, Inc. (USA) .... [9451-59]

Sessions 11 and 12 run concurrently with sessions 14, 15, and 16.

SESSION 11 . . . . WED 1:30 PM TO 4:20 PM

Uncooled FPAs and Applications I

Session Chairs: **Masafumi Kimata,** Ritsumeikan Univ. (Japan); **Stefan T. Baur,** Raytheon Vision Systems (USA)

Uncooled infrared focal plane array imaging in China *(Invited Paper)*, Shuyu Lei, Hui Fang, North GuangWei Technology Inc. (China) . . . . [9451-43]

Uncooled infrared detector and imager development at DALI technology, Lijun Jiang, Zhejiang Dali Technology Co., Ltd. (China) . . . . [9451-44]

BAE Systems' SMART Chip Camera FPA development *(Invited Paper)*, Louise C. Sengupta, Pierre-Alain Auroux, Donald D. McManus, D. Ahmasi Harris, Richard J. Blackwell, Jeffrey F. Bryant, Evan Binkerd, Mihir Boal, BAE Systems (USA) . . . . [9451-45]

Advanced uncooled sensor product development *(Invited Paper)*, Adam M. Kennedy, Paolo Masini, Mark J. Lamb, Jeff Hamers, Thomas A. Kocian, Eli E. Gordon, Raytheon Co. (USA); William J. Parrish, Ross E. Williams, Seek Thermal, Inc. (USA) . . . . [9451-46]

On-orbit performance of the compact infrared camera (CIRC) with uncooled infrared detector, Haruyoshi Katayama, Michito Sakai, Eri Kato, Yasuhiro Nakajima, Toshiyoshi Kimura, Japan Aerospace Exploration Agency (Japan); Koji Nakau, Hokkaido Univ. (Japan) . . . . [9451-47]

Low-SWaP shutterless uncooled video core by SCD, Udi Mizrahi, Yair Lury, Yaakov Gridish, Shahar Yuval, Nickolay Syrel, Yaron Shamay, Roman Meshorer, Roman Iosevich, Shibolet L. Horesh, SCD SemiConductor Devices (Israel) . . . . [9451-48]

SESSION 12 . . . . WED 4:20 PM TO 6:00 PM

Uncooled FPAs and Applications II

Session Chairs: **Colin E. Reese,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Kevin C. Liddiard,** Electro-optic Sensor Design (Australia); **Charles M. Hanson,** SenseIR Solutions, LLC (USA)

Improving the shutterless compensation method for TEC-less microbolometer-based infrared cameras, Alexander Tempelhahn, Helmut Budzier, Volker Krause, Gerald Gerlach, Technische Univ. Dresden (Germany) . . . . [9451-49]

Implementation and performance of shutterless uncooled micro-bolometer cameras, Jo Das, Danny De Gaspari, Philippe Cornet, Pieter D. Deroo, Jan P. Vermeiren, Xenics NV (Belgium); Patrick J. Merken, Xenics NV (Belgium) and Royal Military Academy (Belgium). . . . . [9451-50]

Shutters with embedded processors, Stanley W. Stephenson, Melles Griot (USA) . . . . [9451-51]

Integration of a patterned gold-black absorber with a VO_x-based bolometer for enhanced device performance, Evan M. Smith, Univ. of Central Florida (USA) and Plasmonics, Inc. (USA); Deep Panjwani, Univ. of Central Florida (USA); James C. Ginn III, Christopher J. Long, Plasmonics, Inc. (USA); Robert E. Peale, Univ. of Central Florida (USA); David J. Shelton, Joshua D. Perlstein, Plasmonics, Inc. (USA); Christian W. Smith, Univ. of Central Florida (USA) . . . . [9451-52]

Three-dimensional plasmonic metamaterial absorbers based on all metal structures, Shinpei Ogawa, Daisuke Fujisawa, Mitsubishi Electric Corp. (Japan); Masafumi Kimata, Ritsumeikan Univ. (Japan). [9451-53]

SESSION 14 . . . . WED 10:40 AM TO 12:10 PM

Alternative Approaches and Tools in IR Optical Design I

Session Chairs: **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Jasbinder S. Sanghera,** U.S. Naval Research Lab. (USA)

> *This poster may also be given as an oral presentation in this session*
> **Survivability of Corning durable silver-based multispectral mirrors,** Leonard G. Wamboldt, Corning Incorporated (USA) . . . . [9451-101]

Diffractive optics technologies in infrared systems *(Invited Paper)*, Yakov G. Soskind, DHPC Technologies (USA) . . . . [9451-60]

Varo-Achro-Phobia: the fear of broad spectrum zoom optics, Christopher C. Alexay, Troy A. Palmer, StingRay Optics, LLC (USA) . . . [9451-61]

Improved optical-to-mechanical software export process for precision systems, Ian B. Murray, Jerry Ma, BAE Systems (USA). . . . . [9451-62]

Cost-effective lightweight mirrors for aerospace and defense, Kenneth S. Woodard, Lovell E. Comstock, Leonard G. Wamboldt, Joseph C. Crifasi, Brian P. Roy, Corning Incorporated (USA) . . . . [9451-63]

Lunch/Exhibition Break . . . . .Wed 12:10 pm to 1:30 pm

SESSION 15 . . . . WED 1:30 PM TO 2:10 PM

Alternative Approaches and Tools in IR Optical Design II

Session Chairs: **Jay N. Vizgaitis,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Christopher C. Alexay,** StingRay Optics, LLC (USA); **Jasbinder S. Sanghera,** U.S. Naval Research Lab. (USA)

An ultra-low surface finish process for 6061-Al mirrors, Leonard G. Wamboldt, Corning Incorporated (USA) . . . . [9451-64]

TBD *(Invited Paper)*, ... [9451-65]

SESSION 16 . . . . .WED 2:10 PM TO 4:40 PM

Cryogenic Detector Coolers

Session Chairs: **Richard M. Rawlings,** DRS Technologies, Inc. (USA); **Sergey V. Riabzev,** RICOR-Cryogenic & Vacuum Systems (Israel); **Ingo N. Ruehlich,** AIM INFRAROT-MODULE GmbH (Germany); **Alexander Veprik,** SCD SemiConductor Devices (Israel)

Miniature cryocooler developments for high-operating temperatures at Thales Cryogenics, Roel Arts, Thales Cryogenics B.V. (Netherlands); Jean-Yves Martin, Sebastien Van Acker, Thales Cryogénie S.A. (France); Daniel Willems, Jeroen C. Mullié, Frank Bots, Mark Tops, Thales Cryogenics B.V. (Netherlands); Julien Le Bordays, Thierry Etchanchu, Thales Cryogénie S.A. (France); Tonny Benschop, Thales Cryogenics B.V. (Netherlands). . . . . [9451-66]

Development and optimization progress with Ricor's cryocoolers for HOT IR detectors, Sergey V. Riabzev, RICOR-Cryogenic & Vacuum Systems (Israel) . . . . [9451-67]

Miniature linear cryocoolers for HOT applications, Ingo N. Ruehlich, Markus Mai, Carsten Rosenhagen, Andreas Withopf, Sebastian Zehner, AIM INFRAROT-MODULE GmbH (Germany) . . . . [9451-68]

Multi slope warm-up calorimetry of integrated Dewar-detector assemblies, Alexander Veprik, Baruch Shlomovich, SCD SemiConductor Devices (Israel); Avi Tuito, Israel Ministry of Defense (Israel) . . . . [9451-69]

Microsat cryocooler system, Carl S. Kirkconnell, Lauren S. Shaw, Jacinto Dominguez, Michael J. Ellis, Iris Technology Corp. (USA) . . . . [9451-70]

Advanced Ricor's cryocoolers for high-end IR missile warning systems and ruggedized platforms, Sergey V. Riabzev, RICOR-Cryogenic & Vacuum Systems (Israel) . . . . [9451-71]

CONFERENCE 9451

Thursday 23 April

SESSION 17. . . . . .THU 8:00 AM TO 10:30 AM

HgCdTe

Session Chairs: **Whitney Mason,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Michel Vuillermet,** SOFRADIR (France)

RMS noise modeling and detection for high-reliability HgCdTe infrared focal plane arrays development, Augustin Cathignol, Guillaume Vauquelin, Alexandre Brunner, Vincent Destefanis, SOFRADIR (France). . . . . [9451-72]

MCT by MBE on GaAs at AIM: state of the art and roadmap, Heinrich Figgemeier, Jan Wenisch, Detlef Eich, Stefan Hanna, Wilhelm Schirmacher, Holger Lutz, Timo Schallenberg, Rainer Breiter, AIM INFRAROT-MODULE GmbH (Germany). . . . . [9451-73]

Dark current characterization of very long-wavelength HgCdTe photodetectors, Weida Hu, Shanghai Institute of Technical Physics (China) . . . . [9451-74]

Improved MCT LWIR modules for demanding imaging applications, Rainer Breiter, Heinrich Figgemeier, Holger Lutz, Joachim C. Wendler, Stefan Rutzinger, Timo Schallenberg, AIM INFRAROT-MODULE GmbH (Germany) . . . . [9451-75]

Stress effects on electrical transportation properties of HgCdTe film, Pengyun Song, Xing Chen, Shan Zhang, Shanghai Institute of Technical Physics (China); Zhenhua Ye, Shanghai Institute of Technical Physics (China); Xiaoning Hu, Shanghai Institute of Technical Physics (China) . . . . [9451-76]

Low-dark current p-on-n MCT detector in long and very long-wavelength infrared, Cyril Cervera, Nicolas Baier, Olivier Gravrand, Olivier Boulade, Laurent Mollard, Commissariat à l'Énergie Atomique (France); Gérard Destéfanis, CEA-LETI (France); Vincent Moreau, Jean-Paul Zanatta, Commissariat à l'Énergie Atomique (France) . . . . [9451-77]

TBD *(Invited Paper)*, ... [9451-78]

SESSION 18 . . . . THU 11:00 AM TO 12:00 PM

A Word from the Masters

Session Chair: **Paul R. Norton,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

An IR journey *(Invited Paper)*, Michael A Kinch, DRS Sensors & Targeting Systems, Inc. (USA). . . . . [9451-79]

An IR castle *(Invited Paper)*, Gérard Destéfanis, CEA-LETI (France) . . . [9451-80]

Lunch/Exhibition Break . . . . Thu 12:00 pm to 1:30 pm

SESSION 19 . . . . THU 1:30 PM TO 2:40 PM

Reducing the Pitch

Session Chair: **Ronald G. Driggers,** St. Johns Optical Systems (USA)

Reducing pixel geometries with MOVPE grown MCT arrays, R. Kennedy McEwen, David Jeckells, Sudesh K. Bains, Selex ES (United Kingdom) [9451-81]

Update on 10 µm pixel pitch MCT-based focal plane array with enhanced functionalities, Yann Reibel, Thibault Augey, Laurent Baud, Nicolas Péré-Laperne, Julien Roumegoux, Laurent Rubaldo, Olivier Pacaud, SOFRADIR (France) . . . . [9451-82]

Small pixel oversampled focal plane arrays *(Invited Paper)*, John T. Caulfield, Jerry A. Wilson, Cyan Systems (USA); Nibir K. Dhar, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9451-83]

SESSION 20 . . . . .THU 2:40 PM TO 4:40 PM

Smart Processing

Session Chairs: **Paul L. McCarley,** Air Force Research Lab. (USA); **John T. Caulfield,** Cyan Systems (USA)

Hardware acceleration of lucky-region fusion (LRF) algorithm for high-performance real-time video processing, Tyler Browning, Christopher R. Jackson, Furkan Cayci, Univ. of Delaware (USA); Gary W. Carhart, Jony J. Liu, U.S. Army Research Lab. (USA); Fouad E. Kiamilev, Univ. of Delaware (USA) . . . . [9451-84]

Demonstrations of compressive pixel-based on-chip coded aperture temporal imaging of multiple and dynamic unresolved targets *(Invited Paper)*, Christy Fernandez-Cull, Brian M. Tyrrell, Joseph H. Lin, Richard D'Onofrio, MIT Lincoln Lab. (USA) . . . . [9451-85]

An edge-enhanced infrared-visible image fusion method based on NSCT and fuzzy logic, Qiong Zhang, Xavier Maldague, Univ. Laval (Canada) [9451-86]

TBD, ... [9451-87]

SESSION 21 . . . . .THU 4:40 PM TO 5:40 PM

Alternative Photon Detectors and Applications

Session Chair: **Henk Martijn,** IRnova AB (Sweden)

Resonator-QWIP FPA development, Kwong-Kit Choi, Jason N. Sun, Kimberley A. Olver, U.S. Army Research Lab. (USA) . . . . [9451-88]

Thermal infrared sensors at the Jet Propulsion Laboratory: hyperspectral and multispectral remote sensing, William R. Johnson, Simon J. Hook, Jet Propulsion Lab. (USA) . . . . [9451-89]

Theoretical study of QWIP or QDIP IR-FPA non-uniformity correction, Yusuke Matsukura, Fujitsu Labs., Ltd. (Japan) . . . . [9451-90]

CONFERENCE ENDS . . . . 5:40 PM TO 5:40 PM

CONFERENCE 9452

Tuesday–Thursday 21–23 April 2015 • Proceedings of SPIE Vol. 9452

Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXVI

Conference Chairs: **Gerald C. Holst,** JCD Publishing (USA); **Keith A. Krapels,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Program Committee: **Gary H. Ballard,** U.S. Army Research, Development and Engineering Command (USA); **Gisele Bennett,** Georgia Institute of Technology (USA); **Piet Bijl,** TNO Defence, Security and Safety (Netherlands); **James A. Buford Jr.,** U.S. Army Research, Development and Engineering Command (USA); **James A. Dawson,** Dynetics, Inc. (USA); **Ronald G. Driggers,** St. Johns Optical Systems (USA); **Richard L. Espinola,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **David P. Forrai,** L-3 Communications Cincinnati Electronics (USA); **Jonathan G. Hixson,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Alan Irwin,** Santa Barbara Infrared, Inc. (USA); **Eddie L. Jacobs,** Univ. of Memphis (USA); **Terrence S. Lomheim,** The Aerospace Corp. (USA); **R. Lee Murrer Jr.,** Millennium Engineering and Integration Co. (USA); **Teresa L. Pace,** SenTech, LLC- A DSCI Co. (USA); **Hector M. Reyes,** Raytheon Co. (USA); **Endre Repasi,** Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); **Joseph P. Reynolds,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Bernard M. Rosier,** ONERA (France); **Michael A. Soel,** FLIR Systems, Inc. (USA); **Curtis M. Webb,** Northrop Grumman Electronic Systems (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 8:30 AM TO 11:50 AM

Testing and Systems

Session Chairs: **Alan Irwin,** Santa Barbara Infrared, Inc. (USA); **Curtis M. Webb,** Northrop Grumman Electronic Systems (USA)

Black-box imager characterization, from measurements to modeling range performance *(Invited Paper)*, David P. Haefner, Stephen D. Burks, Brian P. Teaney, U.S. Army RDECOM CERDEC NVESD (USA) . . . . [9452-1]

Characterizing a high-resolution CRT display performance using a Prichard photometer with microscanner, Balvinder Kaur, Jeff T. Olson, Jonathan G. Hixson, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . [9452-2]

Validating machine vision MRT performance against trained observer performance for linear shift invariant sensors, Stephen D. Burks, Joshua M. Doe, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . [9452-3]

Advanced E-O test capability for Army Next-Generation Automated Test System (NGATS), Fred King, Steve W. McHugh, Steve Errea, James McKechnie, Brian Nehring, Gregory P. Matis, Santa Barbara Infrared, Inc. (USA) . . . . [9452-4]

Signal intensity transfer function determination on thermal systems with stray light and scattering present, Stephen D. Burks, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9452-5]

Measuring noise equivalent irradiance of a digital short-wave infrared imaging system using a broadband source to simulate the night spectrum, Tim Robinson, John Green, Esterline Control & Communication Systems (USA) . . . . [9452-6]

Statistical analysis of target acquisition sensor modeling experiments, Dawne M. Deaver, Steven K. Moyer, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9452-7]

Panoramic sensor requirements for military vehicles, Orges Furxhi, Ronald G. Driggers, St. Johns Optical Systems (USA); Bradley L. Preece, Keith A. Krapels, U.S. Army Night Vision & Electronic Sensors Directorate (USA) [9452-8]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:00 pm

SESSION 2 . . . . TUE 1:00 PM TO 3:00 PM

Targets, Backgrounds and Atmospherics

Session Chairs: **Richard L. Espinola,** U.S. Army RDECOM CERDEC NVESD (USA); **Endre Repasi,** Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); **Bernard M. Rosier,** ONERA (France)

Simulation of a polarized laser beam reflected at the sea surface: modeling and validation, Frédéric Schwenger, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany) . . . . [9452-9]

Detector integration time-dependent atmospheric turbulence imaging simulation, Todd W. Du Bosq, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Endre Repasi, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany). . . . . [9452-10]

Image enhancement methods for turbulence mitigation and the influence of different color spaces, Claudia S. Huebner, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany) . . . . [9452-11]

Automatic parameter estimation for atmospheric turbulence mitigation techniques, Stephen Kozacik, Aaron L. Paolini, Eric J. Kelmelis, EM Photonics, Inc. (USA). . . . . [9452-12]

Atmospheric turbulence and sensor system effects on biometric algorithm performance, Richard L. Espinola, Kevin R. Leonard, U.S. Army RDECOM CERDEC NVESD (USA); Kenneth A. Byrd, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Guy Potvin, Defence Research and Development Canada, Valcartier (Canada) . . . . [9452-13]

An adaptive tracker for ShipIR/NTCS, Srinivasan Ramaswamy, David A. Vaitekunas, W. R. Davis Engineering, Ltd. (Canada). . . . . [9452-14]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. . . . . TUE 6:00 PM TO 12:00 AM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

New night vision goggle gain definition, Vyacheslav B. Podobedov, George P. Eppeldauer, Thomas C. Larason, National Institute of Standards and Technology (USA) . . . . [9452-38]

Application and validation of a S/W developed for IR signal simulation by using the measured data from a moving test ship, Kuk-Il Han, Dong-Geon Kim, Jun-Hyuk Choi, Tae-Kuk Kim, Chung-Ang Univ. (Korea, Republic of) . . . . [9452-39]

Contrast performance modeling of broadband IR imaging systems with tunable filter fore-optics, Van A. Hodgkin, U.S. Army RDECOM CERDEC NVESD (USA). . . . . [9452-40]

A real-time contrast enhancement using adaptive histogram threshold for a FLIR camera, Sunmi Oh, Samsung Digital City (Korea, Republic of); Gyu-Hee Park, SK Telecom (Korea, Republic of) . . . . [9452-41]

Optical design of an LWIR imaging polarimetric camera, Sławomir Gogler, Military Univ. of Technology (Poland) . . . . [9452-42]

DEFENSE + SECURITY

CONFERENCE 9452

Wednesday 22 April

SESSION 3 . . . . WED 8:10 AM TO 10:00 AM

Modeling I

Session Chairs: **Keith A. Krapels,** U.S. Army RDECOM CERDEC NVESD (USA); **Gisele Bennett,** Georgia Institute of Technology (USA); **Piet Bijl,** TNO Defence, Security and Safety (Netherlands); **James A. Dawson,** Dynetics, Inc. (USA); **Jonathan G. Hixson,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Simulation-based sensor modeling and at-range target detection characterization *(Invited Paper)*, Corey D. Packard, Peter L. Rynes, Allen R. Curran, ThermoAnalytics, Inc. (USA) . . . . [9452-15]

Probability of detection using ShipIR/NVIPM, David A. Vaitekunas, W. R. Davis Engineering, Ltd. (Canada); Gerald C. Holst, JCD Publishing (USA); Srinivasan Ramaswamy, W. R. Davis Engineering, Ltd. (Canada) . . . . . [9452-16]

A TRM4 component for the night vision integrated performance model, Joseph P. Reynolds, Brian P. Teaney, U.S. Army RDECOM CERDEC NVESD (USA); Todd W. Du Bosq, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Endre Repasi, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany). . . . . [9452-17]

A low-light performance survey of commercially available camera modules, Bradley L. Preece, David M. Tomkinson, Joseph P. Reynolds, U.S. Army RDECOM CERDEC NVESD (USA) . . . . [9452-18]

Depth of field in modern thermal imaging, Norbert Schuster, John W. Franks, Umicore Electro-Optic Materials (Belgium). . . . . [9452-19]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 4 . . . . .WED 1:00 PM TO 2:30 PM

Modeling II

Session Chairs: **Ronald G. Driggers,** St. Johns Optical Systems (USA); **David P. Forrai,** L-3 Communications Cincinnati Electronics (USA); **Eddie L. Jacobs,** The Univ. of Memphis (USA); **Terrence S. Lomheim,** The Aerospace Corp. (USA)

Optimum viewing distance *(Invited Paper)*, Gerald C. Holst, JCD Publishing (USA) . . . . [9452-20]

Optimal design of a compressive sensing imaging system, Bradley L. Preece, U.S. Army RDECOM CERDEC NVESD (USA); Todd W. Du Bosq, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Nader M. Namazi, Georges T. Nehmetallah, The Catholic Univ. of America (USA) . . . . [9452-21]

Block randomization versus complete randomization of human perception stimuli: Is there a difference?, Steven K. Moyer, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Elizabeth R. Uhl, U. S. Army Research Institute (USA) . . . . [9452-22]

Modeled performance of low-light digital imagers, Joseph P. Reynolds, Bradley L. Preece, U.S. Army RDECOM CERDEC NVESD (USA) . . . . . [9452-23]

SESSION 5 . . . . WED 2:30 PM TO 5:00 PM

Modeling III

Session Chairs: **Teresa L. Pace,** DSCI (USA); **Hector M. Reyes,** Raytheon Co. (USA); **Joseph P. Reynolds,** U.S. Army RDECOM CERDEC NVESD (USA); **Michael A. Soel,** FLIR Systems, Inc. (USA)

Legacy modeling and range prediction comparison: NV-IPM versus SSCamIP and NVTherm, Jonathan G. Hixson, Philip I. Richardson, Balvinder Kaur, David M. Tomkinson, Brian P. Teaney, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9452-24]

Custom component generation in the night vision integrated performance model, Brian P. Teaney, David P. Haefner, U.S. Army RDECOM CERDEC NVESD (USA); Stephen D. Burks, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9452-25]

Investigating the validity of the networked imaging sensor model in field of view search, Melvin H. Friedman, U.S. Army RDECOM CERDEC NVESD (USA); Eric A. Flug, Steven K. Moyer, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9452-26]

Model of Large-format EO-IR sensor for calculating the probability of detection and false alarm for fixed and moving targets, Andrew R. Korb, Korb Satellite Systems (USA) . . . . [9452-27]

Face acquisition camera design using the NV-IPM image generation tool, Kenneth A. Byrd, Joseph P. Reynolds, U.S. Army Night Vision & Electronic Sensors Directorate (USA). . . . . [9452-28]

Detection range estimation model for LWIR polarmetric camera, Sławomir Gogler, Military Univ. of Technology (Poland) . . . . [9452-29]

Thursday 23 April

SESSION 6 . . . . THU 9:00 AM TO 12:10 PM

HWIL

Session Chairs: **James A. Buford Jr.,** U.S. Army Research, Development and Engineering Command (USA); **R. Lee Murrer Jr.,** Millennium Engineering and Integration Co. (USA); **Gary H. Ballard,** U.S. Army Research, Development and Engineering Command (USA)

Scene projection technology enhancements for testing infrared imaging sensors in a simulated environment, Heard S. Lowry, Aerospace Testing Alliance (USA) . . . . [9452-30]

Development of an ultrahigh-temperature infrared scene projector at Santa Barbara Infrared Inc., Gregory Franks, Joseph D. Laveigne, Tom Danielson, Santa Barbara Infrared, Inc. (USA); John M. Lannon Jr., Scott H. Goodwin, RTI International (USA); Kevin Sparkman, Santa Barbara Infrared, Inc. (USA) . . . . [9452-31]

Test pixels for high-temperature infrared scene projection, Christopher J. Fredricksen, LRC Engineering, Inc. (USA); Seth Calhoun, Stephen Trewick, Aubrey Coffey, Edward Dein, Kevin R. Coffey, Robert E. Peale, Univ. of Central Florida (USA); Joseph D. LaVeigne, Gregory Franks, Tom Danielson, Santa Barbara Infrared, Inc. (USA); John M. Lannon Jr., Scott H. Goodwin, RTI International (USA). . . . . [9452-32]

Resolution specification for infrared scene projectors used in hardware-in-the-loop testing, Joseph D. LaVeigne, Gregory Franks, Tom Danielson, Santa Barbara Infrared, Inc. (USA); Breck A. Sieglinger, William L. Herald, MacAulay-Brown, Inc. (USA). . . . . [9452-33]

Spectral homogenization techniques for the hyperspectral image projector, Logan E. Hillberry, Colorado School of Mines (USA); Joseph P. Rice, National Institute of Standards and Technology (USA). [9452-34]

Advances in iterative non-uniformity correction techniques for infrared scene projection, Tom Danielson, Joseph D. LaVeigne, Gregory Franks, Marcus Prewarski, Brian Nehring, Santa Barbara Infrared, Inc. (USA) . . [9452-35]

Computing the total atmospheric refraction for real-time optical imaging sensor simulation, Richard F. Olson Jr., U.S. Army Research, Development and Engineering Command (USA). . . . . [9452-36]

Memory efficient atmospheric effects modeling for infrared scene generators, Çaglar Kavak, Seçkin Özsaraç, TÜBİTAK BİLGEM İLTAREN (Turkey) . . . . [9452-37]

CONFERENCE 9453

Tuesday–Wednesday 21–22 April 2015 • Proceedings of SPIE Vol. 9453

Window and Dome Technologies and Materials XIV

Conference Chair: **Brian J. Zelinski,** Raytheon Missile Systems (USA)

Program Committee: **Rick Gentilman,** Raytheon Integrated Defense Systems (USA); **Daniel C. Harris,** Naval Air Warfare Ctr. Weapons Div. (USA); **Brian K. Jones,** U.S. Army Research, Development and Engineering Command (USA); **John S. McCloy,** Washington State Univ. (USA); **Richard Porter,** Air Force Research Lab. (USA); **Michael E. Thomas,** Johns Hopkins Univ. Applied Physics Lab. (USA); **Randal W. Tustison,** Consultant (USA); **Martin Winterling,** UTC Aerospace Systems (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 8:00 AM TO 10:00 AM

Advances in Mid-Wavelength Infrared Window Technology

Session Chair: **Richard Gentilman,** Raytheon Co. (USA)

SESSION 2 . . . . .TUE 10:30 AM TO 11:50 AM

Window and Dome Technology Overviews

Session Chair: **Brian J. Zelinski,** Raytheon Missile Systems (USA)

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . .TUE 1:20 PM TO 3:00 PM

Metrology and Finishing of Flat, Free-Form, and Conformal Optics

Session Chair: **Daniel C. Harris,** Naval Air Warfare Ctr. Weapons Div. (USA)

SESSION 4 . . . . TUE 3:30 PM TO 5:50 PM

Novel Processing and Applications of Optical Windows, Domes, and Coatings

Session Chair: **Michael E. Thomas,** Johns Hopkins Univ. (USA)

DEFENSE + SECURITY

Wednesday 22 April

SESSION 5 . . . . .WED 8:00 AM TO 10:00 AM

Computational Modeling of Optical and Mechanical Properties

Session Chair: **John S. McCloy,** Washington State Univ. (USA)

Electronic-band structures and optical properties of transition metal-doped zinc oxide, Esakkimuthuraju Murugan, Mahesh Rajendran, Badrinath Vadakkapattu Canthadai, Venugopal Reddy Paduru, Sreekanth Tirumala, Vidya Jyothi Institute of Technology (India). . . . . [9453-22]

Role of impactor properties on computational simulation of sand impact damage in transparent ceramic windows, Robert Schultz, The Univ. of Arizona (USA); Ibrahim Guven, Virginia Commonwealth Univ. (USA); Brian J. Zelinski, Raytheon Missile Systems (USA) . . . . [9453-23]

Computational modeling of sand impact damage in coated, transparent ceramic windows, Shanna Tune, Robert Schultz, The Univ. of Arizona (USA); Ibrahim Guven, Virginia Commonwealth Univ. (USA); Brian J. Zelinski, Raytheon Missile Systems (USA). . . . . [9453-24]

New ZnS interatomic potential for molecular dynamics simulations, Erin K. Boland, Raytheon Missile Systems (USA); Krishna Muralidharan, The Univ. of Arizona (USA); Brian J. Zelinski, Raytheon Missile Systems (USA); Stefan Bringuier, The Univ. of Arizona (USA) . . . . [9453-25]

Stress analysis of optical coatings for improved durability and performance of high-end optical components, Shay Joseph, Anna Gleizer, Doron Yadlovker, Arit E. Shinman-Avraham, Rafael Advanced Defense Systems Ltd. (Israel) . . . . [9453-26]

Internal two-phase cooling of an aerodynamically heated LWIR window, Brian Tucker, Joshua Sole, Mainstream Engineering (USA) . . . . [9453-27]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9454

Monday–Thursday 20–23 April 2015 • Proceedings of SPIE Vol. 9454

Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XX

Conference Chairs: **Steven S. Bishop,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Jason C. Isaacs,** Naval Surface Warfare Ctr. Panama City Div. (USA)

Program Committee: **Benjamin E. Barrowes,** U.S. Army Engineer Research and Development Ctr. (USA); **Ryan R. Close,** U.S. Army Night Vision & Electronics Sensors Directorate (USA); **Leslie M. Collins,** Duke Univ. (USA); **Gerald J. Dobeck,** Naval Surface Warfare Ctr. Panama City Div. (USA); **Anthony A. Faust,** Defence Research and Development Canada, Suffield (Canada); **Tesfaye G-Michael,** Naval Surface Warfare Ctr. Panama City Div. (USA); **Gregory Garcia,** Naval Surface Warfare Ctr. Panama City Div. (USA); **James M. Keller,** Univ. of Missouri-Columbia (USA); **Aaron LaPointe,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Henric Östmark,** Swedish Defence Research Agency (Sweden); **Motoyuki Sato,** Tohoku Univ. (Japan); **Waymond R. Scott Jr.,** Georgia Institute of Technology (USA); **Richard C. Weaver,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Monday 20 April

SESSION 1. . . . . MON 8:30 AM TO 9:50 AM

Technology Mélange I

Session Chairs: **Denis M. Reidy,** Naval Explosive Ordnance Disposal Technology Div. (USA); **Leslie M. Collins,** Duke Univ. (USA)

Forecasting the soil-dependent performance of ground-penetrating radar by means of a conventional field moisture sensor, Markus Loewer, Jan Igel, Leibniz Institute for Applied Geosciences (Germany) . . . . [9454-1]

Stand-off explosive detection utilizing low-power stimulated emission nuclear quadrupole resonance detection and sub-wavelength focusing wideband super lens, William Mouyos, John Apostolos, Judy Feng, Walter Chase, AMI Research and Development (USA) . . . . [9454-2]

Minimally disruptive schedule repair for MCM Missions, Kalyan M. Gupta, Matthew Molineaux, Bryan L. Auslander, Philip G. Moore, Knexus Research (USA) . . . . [9454-3]

Fusion of iECO image descriptors for buried explosive hazard detection in forward-looking imagery, Stanton R. Price, Derek T. Anderson, Mississippi State Univ. (USA); James M. Keller, Univ. of Missouri-Columbia (USA) . . [9454-4]

SESSION 2 . . . . MON 10:40 AM TO 12:00 PM

Technology Mélange II

Session Chairs: **Zeke Topolosky,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Joe Keranen,** White River Technologies, Inc. (USA)

Detection of concealed targets using spintronic microwave sensor, Lei Fu, Yongsheng Gui, Can-Ming Hu, Univ. of Manitoba (Canada); Yang Xiao, Mounir Jaidann, Hong Guo, McGill Univ. (Canada); Hakima Abou-Rachid, Defence Research and Development Canada, Valcartier (Canada) . . . . [9454-5]

Differential excitation spectroscopy for detection of common explosives: ammonium nitrate and urea nitrate, Boyd V. Hunter, Jason M. Cox, Kestrel Corp. (USA); Michael A. Miller, Southwest Research Institute (USA); Richard V. Hunter, Paul Harrison, Levi Van Bastian, William P. Walters, Kestrel Corp. (USA) . . . . [9454-6]

Using a blackboard architecture or expert system to identify obfuscated targets from symptoms, Jeremy Straub, Univ. of North Dakota (USA) . [9454-7]

Efficiency of using the spectral dynamics analysis for pulsed THz spectroscopy of both explosive and other materials, Vyacheslav A. Trofimov, Svetlana A. Varentsova, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9454-8]

Lunch Break . . . . .Mon 12:00 pm to 1:30 pm

SESSION 3 . . . . MON 1:30 PM TO 3:10 PM

Electromagnetic Induction I

Session Chairs: **Rajiv Suri,** U.S. Army Research, Development and Engineering Command (USA); **Alina Zare,** Univ. of Missouri-Columbia (USA)

Fuzzy logic-based IED/landmine detection sensor evaluation methodology, Canicious G. Abeynayake, Defence Science and Technology Organisation (Australia). . . . . [9454-9]

Explosive hazard detection using sensor fusion and multiple kernel learning with downward-looking GPR and EMI sensor data, Anthony Pinar, Michigan Technological Univ. (USA); Matthew P. Masarik, Jack Kelly, Michigan Tech Research Institute (USA); Timothy C. Havens, Michigan Technological Univ. (USA); Joseph W. Burns, Brian T. Thelen, Michigan Tech Research Institute (USA); John Becker, Michigan Technological Univ. (USA) . . . . [9454-10]

Extended-range electromagnetic induction sensor concepts, Jonathan S. Miller, Chet Bassani, Gregory Schultz, White River Technologies, Inc. (USA). . . . . [9454-11]

Wideband electromagnetic interrogation of buried explosive hazards using 3D array, Gregory Schultz, Jonathan S. Miller, Chet Bassani, Peter Lorenz, Joe Keranen, White River Technologies, Inc. (USA) . . . . [9454-12]

Munitions detection and discrimination on-the-move: dynamic EMI classification methods and potential in CONUS and OCONUS applications, Gregory Schultz, Jonathan S. Miller, Joe Keranen, Fridon Shubitidze, White River Technologies, Inc. (USA) . . . . [9454-13]

SESSION 4 . . . . MON 3:40 PM TO 4:40 PM

Electromagnetic Induction II

Session Chairs: **Frank Navish III,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Gregory Schultz,** White River Technologies, Inc. (USA)

Non-colocated sensor fusion for buried explosive threat detection for handheld data, Mary Knox, Peter A. Torrione, Leslie M. Collins, Kenneth D. Morton Jr., Duke Univ. (USA) . . . . [9454-14]

Multiple instance dictionary learning for subsurface object detection using handheld EMI, Alina Zare, Univ. of Missouri-Columbia (USA); Brendan Alvey, Univ. of Missouri (USA) and Univ. of Missouri-Columbia (USA); Matthew Cook, Dominic K. Ho, Univ. of Missouri-Columbia (USA) . . . . [9454-15]

Phase response of high- to very high-frequency metal/anomaly detector, Daniel C. Heinz, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); Michael L. Brennan, CACI International Inc. (USA); Michael B. Steer, North Carolina State Univ. (USA); Adam W. Melber, John T. Cua, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA) [9454-16]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

CONFERENCE 9454

Tuesday 21 April

SESSION 5 . . . . TUE 8:20 AM TO 10:00 AM

EO/IR Technologies and Signal Processing I

Session Chairs: **Ryan R. Close,** U.S. Army RDECOM CERDEC NVESD (USA); **Kevin K. Green,** EOIR Technologies (USA)

A probabilistic framework for comparing multi-modality buried threat detection systems with dynamic velocity and sensor activity, Jordan M. Malof, Kenneth D. Morton Jr., Leslie M. Collins, Peter A. Torrione, Duke Univ. (USA) . . . . [9454-17]

Ground vehicle-based LADAR for standoff detection of road-side hazards, Jim Hollinger, Brett Kutscher, LSA Autonomy LLC (USA); Ryan R. Close, U.S. Army RDECOM CERDEC NVESD (USA) . . . . [9454-18]

Airborne thermal infrared hyperspectral imaging of buried objects, Marc-André Gagnon, Alexandrine Huot, Karl-Alexandre Jahjah, Pierre Tremblay, Simon Savary, Vincent Farley, Philippe Lagueux, Éric Guyot, Martin Chamberland, Telops (Canada) . . . . [9454-19]

Learning of an explosive hazard detection pre-screener in forward looking imagery based on adaptive mutation Ravinder Singh, Stanton R. Price, Derek T. Anderson, Mississippi State Univ. (USA) . . . . [9454-20]

Design of a buried explosive hazard pre-screener in forward looking imagery based on Shearlet filtering and image post-processing, Stanton R. Price, Derek T. Anderson, Mississippi State Univ. (USA); James M. Keller, Univ. of Missouri-Columbia (USA) . . . . [9454-21]

SESSION 6 . . . . TUE 10:30 AM TO 11:50 AM

EO/IR Technologies and Signal Processing II

Session Chairs: **Sanjeev Agrawal,** Malaviya National Institute of Technology (India); **Bruce Swett,** EOIR Technologies (USA)

Near real-time, on-the-move multisensor integration and computing framework, Kevin K. Green, Chris Burnette, Chris Geyer, EOIR Technologies (USA); Sanjeev Agarwal, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Diane E. Moulton, EOIR Technologies (USA); Chung D. Phan, U.S. Army RDECOM CERDEC NVESD (USA); Richard M. Lydic Jr., U.S. Army Night Vision & Electronic Sensors Directorate (USA); Bruce Swett, EOIR Technologies (USA) . . . . [9454-22]

Near real-time, on-the-move software PED using VPEF, Kevin K. Green, Chris Geyer, Chris Burnette, EOIR Technologies (USA); Sanjeev Agarwal, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Bruce Swett, EOIR Technologies (USA); Chung D. Phan, Richard M. Lydic Jr., U.S. Army Night Vision & Electronic Sensors Directorate (USA); Diane Deterline, EOIR Technologies (USA) . . . . [9454-23]

Automated on-the-move threat detection within the MOVERS+/VPEF framework, Mark P. Kolba, Joshua R. Walters, Signal Innovations Group, Inc. (USA) . . . . [9454-24]

Real-time buried IED detection and cueing capability in VPEF environment, Bo Ling, Migma Systems, Inc. (USA); Sanjeev Agarwal, U.S. Army RDECOM CERDEC NVESD (USA); Santiago Olivera, Zlatko Vasilkoski, Migma Systems, Inc. (USA); Chung D. Phan, Richard M. Lydic Jr., U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9454-25]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 7 . . . . TUE 1:20 PM TO 2:00 PM

EO/IR Technologies and Signal Processing III

Session Chairs: **Robert H. Luke III,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Mark P. Kolba,** Signal Innovations Group, Inc. (USA)

Multi-scale HOG prescreening algorithm for detection of buried explosive hazards in FL-IR imagery, Kevin E. Stone, James M. Keller, Univ. of Missouri-Columbia (USA) . . . . [9454-26]

An application of log-Gabor filter on road detection in arid environments for forward looking buried object detection, James M. Keller, Pooparat Plodpradista, Mihail Popescu, Univ. of Missouri-Columbia (USA) . . . . . [9454-27]

SESSION 8 . . . . TUE 2:00 PM TO 3:00 PM

Laser Based Chemical Sensing Technologies

Session Chairs: **Ken E. Yasuda,** U.S. Army RDECOM CERDEC NVESD (USA); **Mikella E. Farrell,** U.S. Army Research Lab. (USA)

A method for detecting ultra-low quantities of explosives with use a picosecond laser FAIMS analyzer, Gennadii Kotkovskii, Alexander A. Chistyakov, Ivan P. Odulo, Alexey V. Sychev, National Research Nuclear Univ. MEPhI (Russian Federation); Artem S. Bogdanov, Anatoly N. Perederiy, Moscow State Institute of Radiotechnics, Electronics and Automation (Russian Federation); Evgeny M. Spitsyn, JSC "Research Institute" POLYUS "them. M.F. Stelmaha" (Russian Federation); Alexander V. Shestakov, POLYUS Research and Development Institute (Russian Federation) . . . . [9454-28]

Surface enhanced Raman scattering (SERS) detection of ammonium nitrate (AN) samples fabricated using drop-on-demand inkjet technology, Mikella E. Farrell, Ellen L. Holthoff, Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . [9454-29]

Detection of homemade explosives using Raman excitation at 1064 nm, Eric G. Roy, Claire Dentinger, Claude Robotham, Rigaku Raman Technologies, Inc. (USA) . . . . [9454-30]

SESSION 9 . . . . TUE 3:30 PM TO 5:30 PM

Forward Looking GPR Technologies

Session Chairs: **Brian P. Burns,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Matthew P. Masarik,** Michigan Tech Research Institute (USA)

Clutter and target discrimination in forward-looking ground penetrating radar using sparse structured basis pursuits, Joseph A. Camilo, Jordan M. Malof, Peter A. Torrione, Leslie M. Collins, Kenneth D. Morton Jr., Duke Univ. (USA) . . . . [9454-31]

Deep belief networks for false alarm rejection in forward-looking ground-penetrating radar, John Becker, Timothy C. Havens, Anthony Pinar, Timothy J. Schulz, Michigan Technological Univ. (USA) . . . . [9454-32]

Video processing for explosive hazard detection with forward-looking GPR, Adam Webb, Michigan Tech Research Institute (USA) and Michigan Technological Univ. (USA); Timothy C. Havens, Timothy J. Schulz, Michigan Technological Univ. (USA) . . . . [9454-33]

A synthetic aperture acoustic prototype system, Robert H. Luke III, Steven S. Bishop, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Aaron Chan, U.S. Army RDECOM CERDEC NVESD (USA); Peter M. Gugino, Thomas P. Donzelli, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Mehrdad Soumekh, Soumekh Consultant (USA) . . . . [9454-34]

Explosive hazard detection using MIMO forward-looking ground-penetrating radar, Darren Shaw, Univ. of Missouri (USA); Dominic K. Ho, James M. Keller, Mihail Popescu, Univ. of Missouri-Columbia (USA); Robert H. Luke III, Brian P. Burns, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9454-35]

Advanced processing of standoff sensor data for detecting explosively formed penetrators, Joe Keranen, Gregory Schultz, Fridon Shubitidze, White River Technologies, Inc. (USA); Kancham Chotoo, User Systems, Inc. (USA) . . . . [9454-36]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Fractal descriptors for buried explosive hazard detection in forward looking imagery, Joshua L. Dowdy, Mississippi State Univ. (USA). . . . [9454-61]

Wednesday 22 April

SESSION 10 . . . . WED 8:20 AM TO 10:00 AM

GPR Technologies I

Session Chairs: **Brian C. Barlow,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Peter A. Torrione,** Duke Univ. (USA)

Automatic target detection and discrimination algorithms applicable to ground penetrating radar array data, Canicious G. Abeynayake, Defence Science and Technology Organisation (Australia); Minh D. Tran, Univ. of South Australia (Australia) . . . . [9454-37]

Design and validation of inert homemade explosive simulants for ground penetrating radar, Anthony A. Faust, Brian VanderGaast, Defence Research and Development Canada, Suffield (Canada); John E. McFee, McFysics Consulting (Canada); Cristian Mosquera, Defence Research and Development Canada, Suffield (Canada). . . . . [9454-38]

Deep convolutional neural networks for classifying GPR B-scans, Lance E. Besaw, Phil J. Stimac, Applied Research Associates, Inc. (USA). . . . . . [9454-39]

GPR anomaly detection with robust principal component analysis, Matthew P. Masarik, Joseph W. Burns, Brian T. Thelen, Jack Kelly, Michigan Tech Research Institute (USA); Timothy C. Havens, Michigan Technological Univ. (USA) . . . . [9454-40]

A layer tracking approach to buried surface detection, Peter J. Dobbins, Joseph Wilson, Brandon Smock, Univ. of Florida (USA) . . . . [9454-41]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 11. . . . . WED 1:00 PM TO 2:40 PM

GPR Technologies II

Session Chairs: **Pete Howard,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Matthew P. Masarik,** Michigan Tech Research Institute (USA)

Target signature localization in GPR data by clustering and classification, Daniel Reichman, Kenneth D. Morton Jr., Leslie M. Collins, Peter A. Torrione, Duke Univ. (USA). . . . . [9454-42]

Fast 3D subsurface imaging with stepped-frequency GPR, Matthew P. Masarik, Joseph W. Burns, Brian T. Thelen, Lena Sutter, Michigan Tech Research Institute (USA) . . . . [9454-43]

Fusion of forward-looking infrared camera and down-looking ground penetrating radar for buried target detection, Firat Gurbuz, IPA DEFENCE Ltd. (Turkey) and Hacettepe Univ. (Turkey); Seniha E. Yuksel, Hacettepe Univ. (Turkey); Gozde Bozdagi Akar, Middle East Technical Univ. (Turkey) . . [9454-44]

Detection of deeply buried non-metal objects by ground-penetrating radar using non-negative matrix factorization, Daniel Nabelek, Dominic K. Ho, Univ. of Missouri-Columbia (USA) . . . . [9454-45]

Recognizing subsurface target responses in ground penetrating radar data using convolutional neural networks, Rayn T. Sakaguchi, Kenneth D. Morton Jr., Leslie M. Collins, Peter A. Torrione, Duke Univ. (USA) . . . . [9454-46]

SESSION 12 . . . . WED 3:30 PM TO 4:30 PM

GPR Technologies III

Session Chairs: **Richard C. Weaver,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Lance E. Besaw,** Applied Research Associates, Inc. (USA)

Improving buried threat detection in ground-penetrating radar with transfer learning and metadata analysis, Kenneth A. Colwell, Peter A. Torrione, Leslie M. Collins, Kenneth D. Morton Jr., Duke Univ. (USA) . . . . [9454-47]

Leveraging robust principal component analysis to detect buried explosive threats in handheld ground-penetrating radar data, Dmitry Kalika, Mary Knox, Peter A. Torrione, Leslie M. Collins, Kenneth D. Morton Jr., Duke Univ. (USA) . . . . [9454-48]

Anomaly detection of subsurface objects using handheld ground-penetrating radar, Dominic K. Ho, Univ. of Missouri (USA); Samuel Harris, Univ. of Missouri-Columbia (USA); Alina Zare, Matthew Cook, Univ. of Missouri (USA) . . . . [9454-49]

SESSION 13. . . . . WED 4:30 PM TO 5:10 PM

Neutron Beam

Session Chairs: **Anthony A. Faust,** Defence Research and Development Canada, Suffield (Canada); **J. Paul Farrell,** Brookhaven Technology Group, Inc. (USA)

A kinematically-focused neutron beam system to detect surface and buried threats, J. Paul Farrell, Brookhaven Technology Group, Inc. (USA); Michael Vyvoda, Ted Smick, Noah Smick, GT Advanced Technologies (USA); Noel A. Guardala, Naval Surface Warfare Ctr. Carderock Div. (USA) . . . . [9454-50]

Tagged neutron capabilities for detecting hidden explosives, Sergei G. Belichenko, All-Russia Research Institute of Automatics (Russian Federation) . . . . [9454-51]

Thursday 23 April

SESSION 14 . . . . THU 8:20 AM TO 10:00 AM

Maritime Signal Processing I

Session Chairs: **Tesfaye G-Michael,** Naval Surface Warfare Ctr. Panama City Div. (USA); **John G. Baylog,** Naval Undersea Warfare Ctr. (USA)

Information surfing with the JHU/APL coherent imager, Christopher R. Ratto, Kara R. Shipley, Nathaniel Beagley, Kevin C. Wolfe, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . . [9454-52]

Multiple pass collaborative search in the presence of false alarms, John G. Baylog, Thomas A. Wettergren, Naval Undersea Warfare Ctr. (USA) . . . [9454-53]

A solution to the multiple view object detection problem, Syed U. Gilani, Apoorva Shende, Daniel J. Stilwell, Virginia Polytechnic Institute and State Univ. (USA); Bao Nguyen, Defence Research and Development Canada (Canada) . . . . [9454-54]

Possibilistic context identification for SAS imagery, Xiaoxiao Du, Alina Zare, Univ. of Missouri-Columbia (USA); James T. Cobb, Naval Surface Warfare Ctr. Panama City Div. (USA). . . . . [9454-55]

Dictionary learning for sparse sonar image representations, Jason C. Isaacs, Naval Surface Warfare Ctr. Panama City Div. (USA) . . . . [9454-56]

SESSION 15 . . . . THU 10:30 AM TO 11:50 AM

Maritime Signal Processing II

Session Chairs: **John G. Baylog,** Naval Undersea Warfare Ctr. (USA); **Tesfaye G-Michael,** Naval Surface Warfare Ctr. Panama City Div. (USA)

Investigation of measureable parameters that correlate with automated target recognition performance in synthetic aperture sonar, Julia Gazagnaire, Jason C. Isaacs, Naval Surface Warfare Ctr. Panama City Div. (USA) . . . . [9454-57]

Unsupervised 3D scene understanding and prediction to enable adaptable approximate solutions to the art gallery problem and watchman route problem, Bruce A. Johnson, Vatana An, Naval Surface Warfare Ctr. Panama City Div. (USA); Hairong Qi, The Univ. of Tennessee Knoxville (USA). . . [9454-58]

Polar format algorithm for cooperative radar engagement SAR imaging, Tesfaye G-Michael, Naval Surface Warfare Ctr. Panama City Div. (USA); Rodney G. Roberts, Florida State Univ. (USA); Thomas L. Lewis, Air Force Research Lab. (USA) . . . . [9454-59]

Automated area segmentation for ocean bottom surveys, John C. Hyland, Cheryl M. Smith, Naval Surface Warfare Ctr. Panama City Div. (USA) . . [9454-60]

CONFERENCE 9455

Tuesday–Thursday 21–23 April 2015 • Proceedings of SPIE Vol. 9455

Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XVI

Conference Chair: **Augustus Way Fountain III,** U.S. Army Edgewood Chemical Biological Ctr. (USA)

Program Committee: **Jerome J. Braun,** (USA); **Sylvie Buteau,** Defence Research and Development Canada, Valcartier (Canada); **James P. Carney,** Sandia National Labs. (USA); **Christopher C. Carter,** Johns Hopkins Univ. Applied Physics Lab. (USA); **Darren K. Emge,** U.S. Army Edgewood Chemical Biological Ctr. (USA); **Jason A. Guicheteau,** U.S. Army Edgewood Chemical Biological Ctr. (USA); **Eric J. Houser,** U.S. Dept. of Homeland Security (USA); **Chris R. Howle,** Defence Science and Technology Lab. (United Kingdom); **Harry Ing,** Bubble Technology Industries, Inc. (Canada); **Timothy J. Johnson,** Pacific Northwest National Lab. (USA); **Aaron LaPointe,** U.S. Army RDECOM CERDEC NVESD (USA); **Paul M. Pellegrino,** U.S. Army Research Lab. (USA); **James Placke Jr.,** Y-12 National Security Complex (USA); **Cynthia R. Swim,** U.S. Army Edgewood Chemical Biological Ctr. (USA); **Anna Tedeschi,** Strategic Analysis, Inc. (USA), U. S. Dept. of Homeland Security {United States); **Steven W. Waugh,** Defense Threat Reduction Agency (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 10:30 AM TO 11:50 AM

Radiological Detection

Session Chair: **James Placke Jr.,**
Y-12 National Security Complex (USA)

Neutron spectroscopy using InP scintillator, Veerendra K. Mathur, Naval Surface Warfare Ctr. Carderock Div. (USA); Johnathan Wensman, Naval Surface Warfare Ctr. Carderock Div. (USA) and Georgetown Univ. (USA); Noel A. Guardala, Naval Surface Warfare Ctr. Carderock Div. (USA); John F. Currie, Georgetown Univ. (USA) . . . . [9455-1]

Subwavelength films for standoff radiation dosimetry, Kyle J. Alvine, Bruce E. Bernacki, Wendy D. Bennett, Daniel L. Edwards, Albert M. Mendoza, Jonathan D. Suter, Pacific Northwest National Lab. (USA). . . . . [9455-2]

Dehydration of uranyl nitrate hexahydrate to uranyl nitrate trihydrate under ambient conditions as observed via dynamic infrared reflectance spectroscopy, Timothy J. Johnson, Lucas E. Sweet, David E. Meier, Pacific Northwest National Lab. (USA); Edward J. Mausolf, Pacific Northwest National Lab. (USA) and Univ. of Nevada, Las Vegas (USA); Eunja Kim, Univ. of Nevada, Las Vegas (USA); Philippe F. Weck, Sandia National Labs. (USA); Edgar C. Buck, Bruce K. McNamara, Pacific Northwest National Lab. (USA). . . . . [9455-3]

Effects of sample preparation on the infrared reflectance spectra of powders, Carolyn S. Brauer, Timothy J. Johnson, Tanya L. Myers, Yin-Fong Su, Thomas A. Blake, Pacific Northwest National Lab. (USA); Brenda M. Forland, Red Rocks Community College (USA) . . . . [9455-4]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 2 . . . . .TUE 1:20 PM TO 3:00 PM

Radiological Detection II

Session Chair: **James Placke Jr.,**
Y-12 National Security Complex (USA)

Use of CLYC spectrometer in counter-terrorism applications, Harry Ing, Bubble Technology Industries, Inc. (Canada) . . . . [9455-5]

Elimination of nuisance alarms through the use of HPGe in primary cargo/ passenger radiation portal applications, Joseph B. McCabe, AMETEK, Inc. (USA) . . . . [9455-6]

Single-device measurement of chemical, radiological, nuclear, and explosive threats, Joseph B. McCabe, AMETEK, Inc. (USA) . . . . [9455-7]

Exploratory research in the HPGe: operation at elevated temperatures to achieve advanced rdeduced nuclear/radiological threat detection systems, Joseph B. McCabe, AMETEK, Inc. (USA) . . . . [9455-8]

Order of magnitude size reduction in HPGe-based radioisotope identification devices (RIID) for the advancement of nuclear/radiological threat detection systems, Joseph B. McCabe, AMETEK, Inc. (USA). . . [9455-9]

SESSION 3 . . . . .TUE 3:30 PM TO 5:10 PM

Biological Detection

Session Chair: **Steven W. Waugh,**
Defense Threat Reduction Agency (USA)

Quartz crystal microbalance biosensor for rapid detection of aerosolized microorganisms, Zdenek Farka, David Kovár, Petr Skládal, Masaryk Univ. (Czech Republic) . . . . [9455-10]

Standoff detection and classification procedure for bioorganic compounds by hyperspectral laser-induced fluorescence, Anita Hausmann, Frank Duschek, Thomas Fischbach, Carsten Pargmann, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); Valeri Alekseyev, Innokenti Sobolev, Larisa Porovkina, Sergey Babichenko, Laser Diagnostic Instruments AS (Estonia); Jürgen Handke, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany) . . . . [9455-11]

Bioaerosol detection and classification using dual excitation wavelength laser-induced fluorescence, Per Jonsson, Pär Wästerby, Per-Åke Gradmark, Julia Hedborg, Anders Larsson, Lars Landström, FOI (Sweden) . . . . . . [9455-12]

Discovery and characterization of anti-PA peptide reagents by bacterial display using a semi-automated method, Deborah A. Sarkes, U.S. Army Research Lab. (USA); Brandi L. Dorsey, Federal Staffing Resources (USA); Amethist S. Finch, Dimitra N. Stratis-Cullum, U.S. Army Research Lab. (USA) . . . . [9455-13]

Multisense chip: continuously working air monitoring system: An integrated system for the detection of airborne biological pathogens on molecular and immunological level, Claudia Gärtner, Holger Becker, Nadine Hlawatsch, Richard Klemm, Sebastian Schattschneider, Christian Moche, microfluidic ChipShop GmbH (Germany) . . . . [9455-14]

Wednesday 22 April

SESSION 4 . . . . WED 1:00 PM TO 4:10 PM

Algorithms for CBRNE Sensing

Session Chair: **Darren K. Emge,**
U.S. Army Edgewood Chemical Biological Ctr. (USA)

Hyperspectral image analysis for detection of explosive substances using IR laser standoff spectroscopy, Jan-Philip Jarvis, Frank Fuchs, Stefan Hugger, Quankui K. Yang, Ralf Ostendorf, Christian Schilling, Wolfgang Bronner, Rachid Driad, Rolf Aidam, Joachim Wagner, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany) . . . . [9455-15]

Massive classification and automated identification of explosives through Raman spectroscopy and artificial neural networks, Salvatore Almaviva, Antonio Palucci, Sabina Botti, Giovanni Dipoppa, Adriana Puiu, ENEA (Italy) . . . . [9455-16]

Bioinspired digital signal processing for fast radionuclide mixture identification, Mathieu Thevenin, Olivier Bichler, Cheick Thiam, Christophe Bobin, Commissariat à l'Énergie Atomique (France). . . . . [9455-17]

Single-wavelength lidar retrieval algorithm of particulate matter concentration using CELiS (compact eyesafe lidar system) a 1.5 µm elastic lidar system, Alan W. Bird, Kori D. Moore, Michael D. Wojcik, Robert Lemon, Utah State Univ. (USA) . . . . [9455-18]

Maximum discrimination approach for classification of nearly identical signatures, Darren K. Emge, U.S. Army Edgewood Chemical Biological Ctr. (USA); Steven Kay, The Univ. of Rhode Island (USA) . . . . [9455-19]

Non-specific sensor arrays for chemical detection, Kevin J. Johnson, U.S. Naval Research Lab. (USA); Christian P. Minor, Nova Research, Inc. (USA) . . . . [9455-20]

Removal of nonresonant background in MCARS spectra using Fourier filtering, Stephen D. Roberson, Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . [9455-21]

Trace explosives detection using photo-thermal infrared imaging spectroscopy (PT-IRIS): theory, modeling, and detection algorithms, Robert Furstenberg, Christopher A. Kendziora, Michael R. Papantonakis, Viet Nguyen, Jeff M. Byers, R. Andrew McGill, U.S. Naval Research Lab. (USA) . . . . [9455-22]

Thursday 23 April

SESSION 5 . . . . .THU 8:00 AM TO 10:20 AM

Chemical Sensing I

Session Chair: **Christopher R. Howle,** Defence Science and Technology Lab. (United Kingdom)

Intracavity optical parametric oscillators based upon orientation-patterned GaAs (OPGaAs): development toward a flexible deep-infrared active hyperspectral imaging system *(Invited Paper)*, David M. Stothard, Fraunhofer Ctr. for Applied Photonics (United Kingdom); Daniel J. Kane, Fraunhofer Ctr, for Applied Photonics (United Kingdom); Peter G. Schunemann, BAE Systems (USA); Malcolm H. Dunn, Malcolm H. Dunn, Univ. of St. Andrews (United Kingdom) . . . . [9455-23]

New plasmonic materials and fabrication tools for near- and mid-infrared sensing *(Invited Paper)*, Otto L. Muskens, Yudong Wang, Leo-Jay Black, Cornelis Hendrik de Groot, Univ. of Southampton (United Kingdom); Arnaud Arbouet, Ctr. d'Elaboration de Matériaux et d'Etudes Structurales (France) . . . . [9455-24]

Detection of chemical clouds using widely tunable quantum cascade lasers, Anish K. Goyal, Petros Kotidis, Erik R. Deutsch, Ninghui Zhu, Mark Norman, Jim Ye, Kostas Zafiriou, Alexander Mazurenko, Block Engineering, LLC (USA). . . . . [9455-25]

Detecting liquid contamination on surfaces using hyperspectral imaging data, Russell E. Warren, EO-Stat, Inc. (USA); David B. Cohn, DBC Technology Corp. (USA); Marc-André Gagnon, Vincent Farley, Telops (Canada) . . . [9455-26]

The development of a wide-field, high-resolution UV Raman hyperspectral imager, Nathaniel R. Gomer, Matthew P. Nelson, ChemImage Corp. (USA); Stanley M. Angel, Univ. of South Carolina (USA) . . . . [9455-27]

Advanced shortwave infrared and Raman hyperspectral sensors for homeland security and law enforcement operations, Matthew P. Nelson, Chuck Gardner, Nathaniel R. Gomer, ChemImage Corp. (USA). . . . . . . [9455-28]

SESSION 6 . . . . THU 10:50 AM TO 11:50 AM

Explosives Sensing

Session Chair: **Aaron LaPointe,** U.S. Army Night Vision & Electronic Sensors Directorate (USA)

Characterization of inkjet-printed explosive materials, Mikella E. Farrell, Ellen L. Holthoff, Logan S. Marcus, Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . [9455-29]

Stand-off detection of explosives and precursors in realistic environments using UV coded aperture Raman spectroscopy, Mattias Svanqvist, Markus Nordberg, Henric Östmark, Swedish Defence Research Agency (Sweden) . . . . [9455-30]

Advances in sublimation studies for particles of explosives, Robert Furstenberg, Tara Abrishami, Michael R. Papantonakis, Christopher A. Kendziora, David R. Mott, R. Andrew McGill, U.S. Naval Research Lab. (USA) . . . . [9455-32]

Lunch/Exhibition Break . . . . Thu 11:50 am to 1:20 pm

SESSION 7 . . . . THU 1:20 PM TO 2:40 PM

Chemical Sensing II

Session Chair: **Jason A. Guicheteau,** U.S. Army Edgewood Chemical Biological Ctr. (USA)

Experimental examination of ultraviolet Raman cross sections of chemical warfare agent simulants, Fredrik Kullander, Lars Landström, Hampus Lundén, Göran Olofsson, Pär Wästerby, Swedish Defence Research Agency (Sweden) . . . . [9455-33]

Photoacoustic chemical sensing: layered systems and excitation source analysis, Logan S. Marcus, Ellen L. Holthoff, Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . [9455-34]

Cooperative use of standoff and UAV sensors for CBRNE detection, William J. Marinelli, Thomas Schmit, Julia Rentz Dupuis, David Manegold, Physical Sciences Inc. (USA); Manal Beshay, Marvin Lav, Intelligent Optical Systems, Inc. (USA). . . . . [9455-35]

Detection of munitions grade chemical warfare agents using Raman excitation at 1064 nm, Eric G. Roy, Rigaku Raman Technologies, Inc. (USA); Phillip G. Wilcox, Soren Hoffland, U.S. Army Edgewood Chemical Biological Ctr. (USA); Ian Pardoe, EXCET, Inc. (USA). . . . . [9455-36]

SESSION 8 . . . . THU 3:30 PM TO 4:50 PM

Chemical Sensing III

Session Chair: **Augustus Way Fountain III,** U.S. Army Edgewood Chemical Biological Ctr. (USA)

A molecularly imprinted polymer (MIP)-coated microbeam MEMS sensor for chemical detection, Ellen L. Holthoff, U.S. Army Research Lab. (USA); Lily Li, Kimberly L. Turner, Tobias Hiller, Univ. of California, Santa Barbara (USA) . . . . [9455-37]

A study of single-beam femtosecond MCARS in trace material detection, Stephen D. Roberson, Paul M. Pellegrino, U.S. Army Research Lab. (USA) . . . . [9455-38]

Differential excitation spectroscopy for detection of chemical threats: DMMP and thiodiglycol, Boyd V. Hunter, Jason M. Cox, Kestrel Corp. (USA); Michael A. Miller, Southwest Research Institute (USA); Paul Harrison, William P. Walters, Kestrel Corp. (USA) . . . . [9455-39]

Breadboard sized photo-acoustic spectroscopy system using an FPGA based lock-in amplifier, John F. Schill, U.S. Army Research Lab. (USA) . . . . [9455-40]

CONFERENCE 9456

Monday–Wednesday 20–22 April 2015 • Proceedings of SPIE Vol. 9456

Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security, Defense, and Law Enforcement Applications XIV

Conference Chair: **Edward M. Carapezza,** EMC Consulting, LLC (USA)

Program Committee: **George Cybenko,** Thayer School of Engineering at Dartmouth (USA); **Panos G. Datskos,** Oak Ridge National Lab. (USA); **Gregory L. Duckworth,** BBN Technologies, a Raytheon Co. (USA); **Susan F. Hallowell,** Transportation Security Lab. (USA), Dept. of Homeland Security (USA); **Todd M. Hintz,** Space and Naval Warfare Systems Command (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Pradeep K. Khosla,** Univ. of California, San Diego (USA); **Daniel Lehrfeld,** Blue Marble Group LLC (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA); **Jordan Wexler,** Raytheon Applied Signal Technology, Inc. (USA)

Monday 20 April

SESSION 1. . . . . MON 8:30 AM TO 11:10 AM

Chemical, Concealed Weapons, Through-the-Wall Sensor and Material Technologies and Systems

Session Chairs: **Panos G. Datskos,** Oak Ridge National Lab. (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Edward M. Carapezza,** EMC Consulting, LLC (USA)

Detection of chemicals using quantum cascade laser spectroscopy *(Keynote Presentation)*, Panos G. Datskos, Marissa E. Morales-Rodríguez, Phillip Bingham, Larry R. Senesac, David Graham, Ilia Ivanov, Kenneth W. Tobin Jr., Oak Ridge National Lab. (USA). . . . . [9456-1]

Demonstration of novel high-power acoustic through-the-wall sensor, Franklin Felber, Starmark, Inc. (USA) . . . . [9456-2]

The use of short and wide x-ray pulses for time-of-flight x-ray Compton scatter imaging in cargo security, Nick Calvert, Marta M. Betcke, Univ. College London (United Kingdom); John R. Cresswell, Univ. of Liverpool (United Kingdom); Alick N. Deacon, The Univ. of Manchester (United Kingdom); Anthony J. Gleeson, Science and Technologies Facilities Council (United Kingdom); Daniel S. Judson, Univ. of Liverpool (United Kingdom); Peter Mason, Rapiscan Systems Ltd. (United Kingdom); Peter A. McIntosh, Science and Technologies Facilities Council (United Kingdom); Edward J. Morton, Rapiscan Systems Ltd. (USA); Paul J. Nolan, Univ. of Liverpool (United Kingdom); James Ollier, Mark G. Procter, Rapiscan Systems Ltd. (United Kingdom); Robert D. Speller, Univ. College London (United Kingdom) . . . . [9456-3]

Consideration of the use of visible light 3D scanning for prisoner contraband possession assessment and other similar purposes, Jeremy Straub, Univ. of North Dakota (USA). . . . . [9456-4]

Optically transparent superhydrophobic coatings for enhanced performance sensing and CSP and CPV power generations, Scott R. Hunter, D. Barton Smith, Georgios Polizos, Daniel A. Schaeffer, Panos G. Datskos, Oak Ridge National Lab. (USA). . . . . [9456-5]

Ultra-strong and electrically conductive graphene fibers, Panos G. Datskos, Ivan Vlassiouk, Oak Ridge National Lab. (USA) . . . . [9456-6]

SESSION 2 . . . . MON 11:10 AM TO 12:10 PM

Counter Sniper, Projectile, and Gunfire Localization

Session Chairs: **Gregory L. Duckworth,** BBN Technologies, a Raytheon Co. (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA)

Acoustic and infrared active shooter detection and reporting, Ron Fowler, Chris Connors, Shooter Detection Systems LLC (USA) . . . . [9456-7]

An agnostic acoustic smart sensor network for hostile fire detection with sensor fusion capability, George Cakiades, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . [9456-8]

Target plane projectile location sensor system, Slobodan Rajic, William R. Lawrence, Panos G. Datskos, Oak Ridge National Lab. (USA); Ross W. Towers, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . [9456-9]

Lunch Break . . . . .Mon 12:10 pm to 1:40 pm

SESSION 3 . . . . .MON 1:40 PM TO 4:30 PM

Infrastructure Protection and Counter Terrorism 1

Session Chairs: **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA); **Gregory L. Duckworth,** Raytheon Cr. (USA)

A low-cost FMCW radar for footprint and personnel detection from a mobile platform, David Boutte, Paul Taylor, AKELA, Inc. (USA) . . . . . . [9456-10]

Optically resonant subwavelength films for tamper-indicating tags and seals, Kyle J. Alvine, Jonathan D. Suter, Bruce E. Bernacki, Wendy D. Bennett, Pacific Northwest National Lab. (USA) . . . . [9456-11]

Multi-capability color night vision HD camera for defense, surveillance, and security applications, Francis Pang, e2v Aerospace and Defense, Inc. (USA) . . . . [9456-12]

Analysis of a mutual assured destruction-like scenario with swarms of non-recallable autonomous robots, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9456-13]

Performance of a buried microphone to detect voice and footsteps, Thyagaraju Damarla, U.S. Army Research Lab. (USA) . . . . [9456-14]

Surveillance systems for intermodal transportation, Miroslav Voznak, VŠB-Technical Univ. of Ostrava (Czech Republic); Sergej Jakovlev, Arunas Andziulis, Klaipeda Univ. (Lithuania) . . . . [9456-15]

Unmanned aerial vehicles (UAVs): a new tool in counterterrorism operations?, Mehmet F. Dörtbudak, Turkish Air War College (Turkey) . [9456-16]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

THIS PROGRAM IS CURRENT AS OF DECEMBER 2014

Tuesday 21 April

SESSION 4 . . . . .TUE 8:00 AM TO 9:20 AM

Cyber Crimes, Cyberterrorism, and Law Enforcement Technologies and Systems

Session Chairs: **George Cybenko,** Thayer School of Engineering at Dartmouth (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Edward M. Carapezza,** EMC Consulting, LLC (USA); **Jordan Wexler,** Raytheon Applied Signal Technology, Inc. (USA)

Deep learning of behaviors *(Keynote Presentation)*, George Cybenko, Thayer School of Engineering at Dartmouth (USA) . . . . [9456-17]

National Institute of Justice: Science and Technology Office initiatives *(Keynote Presentation)*, William A. Ford, U.S. Dept of Justice (USA) . . . [9456-18]

SESSION 5 . . . . TUE 9:20 AM TO 10:40 AM

Cyber Crimes, Cyberterrorism, and Law Enforcement

Session Chair: **Jordan Wexler,** Raytheon Applied Signal Technology, Inc. (USA); **George Cybenko,** Thayer School of Engineering at Dartmouth (USA)

Quantification of moving target cyber defenses, Katheryn A. Farris, George Cybenko, Thayer School of Engineering at Dartmouth (USA). . . . . [9456-19]

Enterprise scale cyber risk assessment and management, Jeff Hughes, Tenet 3, LLC (USA); George Cybenko, Thayer School of Engineering at Dartmouth (USA) . . . . [9456-20]

Tensor transform-based method of image encryption, Artyom M. Grigoryan, Bryan A. Wiatrek, The Univ. of Texas at San Antonio (USA). . . . . [9456-21]

An exact computational method for performance analysis of sequential test algorithms for detecting network intrusions, Xinjia Chen, Frederick W. Lacy, Patrick Carriere, Southern Univ. and A&M College (USA). . . . . . . [9456-22]

SESSION 6 . . . . TUE 11:00 AM TO 12:20 PM

C3I Systems and Technologies 1

Session Chairs: **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

Bayesian truthing as experimental verification of C4ISR sensors, Tomasz P. Jannson, Thomas C. Forrester, Andrew A. Kostrzewski, Physical Optics Corp. (USA) . . . . [9456-23]

Stochastic optimization of space-time constellations, Xinjia Chen, Patrick Carriere, Frederick W. Lacy, Southern Univ. and A&M College (USA) . . [9456-24]

ATAK: situation awareness for the network edge, Kyle Usbeck, Matthew Gillen, Joseph P. Loyall, Andrew Gronosky, Simon Chase, Raytheon BBN Technologies (USA); Todd Krokowski, PAR Government Systems Corp. (USA); Kelly Hanlon, Andrew Scally, WinTec Arrowmaker, Inc. (USA); Joshua Sterling, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Ralph L. Kohler Jr., Richard Newkirk, David Canestrare, Air Force Research Lab. (USA) [9456-25]

Adaptive randomized algorithms for analysis and design of control systems under uncertain environments, Xinjia Chen, Southern Univ. and A&M College (USA) . . . . [9456-26]

Lunch/Exhibition Break . . . . Tue 12:20 pm to 1:40 pm

SESSION 7 . . . . .TUE 1:40 PM TO 3:20 PM

C3I Systems and Technologies II

Session Chairs: **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

Vulnerabilities in GSM technology and feasibility of selected attacks, Miroslav Voznak, Martin Prokes, Miralem Mehic, Lukas Sevcik, Jaroslav Frnda, Martin Mikulec, Zdenka Chmelikova, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . . [9456-27]

PACT DSS: a decision support system for privacy impact assessment of future security investments, Stelios C Thomopoulos, Dimitris Kyriazanos, Anastassios Bravakis, Olga Segou, NCSR Demokritos (Greece) . . . . . . [9456-28]

Anomalies, singularities, and catastrophes in C3ISR systems, Tomasz P. Jannson, Pedram Boghrat, Thomas C. Forrester, Thomas Nielsen, Andrew A. Kostrzewski, Physical Optics Corp. (USA) . . . . [9456-29]

The next-generation of command post computing, Ross Arnold, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . . . [9456-30]

DXBC: a long distance wireless broadband communication system for coastal maritime surveillance applications, Stelios C Thomopoulos, George Vastianos, NCSR Demokritos (Greece). . . . . [9456-31]

SESSION 8 . . . . TUE 3:50 PM TO 5:30 PM

Infrastructure Protection and Counter Terrorism II

Session Chairs: **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

Precision tracking of low radar cross-section targets, Amanda Keeshen, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . [9456-32]

Remote ballistic emplacement of an electro-optical and acoustic target detection and localization system, Aaron West, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . [9456-33]

Picatinny optical detection system (PODS), Gerard Gaeta, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . . . [9456-34]

Installation as a system, Robert Giarratano, Mike Cazzola, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . . . [9456-35]

Flexible fire control system (F2CS), Jose G. Vergara, U.S. Army Armament Research, Development and Engineering Ctr. (USA) . . . . [9456-36]

Wednesday 22 April

SESSION 9 . . . . .WED 8:00 AM TO 9:20 AM

Infrastructure Protection: Emerging Technologies and Future Systems

Session Chairs: **Edward M. Carapezza; Tariq Manzur,** Naval Undersea Warfare Ctr. (USA)

THz technology *(Keynote Presentation)*, Manijeh Razeghi, Northwestern Univ. (USA) . . . . [9456-37]

RF photonics for next-generation electronic warfare *(Keynote Presentation)*, Josh Conway, Defense Advanced Research Projects Agency (USA) . . . . [9456-38]

CONFERENCE 9456

SESSION 10 . . . . WED 9:20 AM TO 10:20 AM

Infrastructure Protection: Undersea and Maritime Technologies and Systems I

Session Chairs: **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA)

Laser beam propagation through an atmospheric transitional and turbulent boundary layer, Richard A. Katz, Naval Undersea Warfare Ctr. (USA) . [9456-39]

Challenges of laser beam propagation near and within the marine boundary layer, Tariq Manzur, Richard A. Katz, Naval Undersea Warfare Ctr. (USA) . . . . [9456-40]

Patterning for success, Theresa Baus, Naval Undersea Warfare Ctr. (USA) . . . . [9456-41]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 11. . . . . WED 1:20 PM TO 4:10 PM

Infrastructure Protection: Undersea and Maritime Technologies and Systems II

Session Chairs: **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA)

Optical metamaterials for submarine applications, Jose G. Barbosa, Naval Undersea Warfare Ctr. (USA) . . . . [9456-42]

Nonlinear acoustic modeling for undersea sensors, Richard A. Katz, Naval Undersea Warfare Ctr. (USA) . . . . [9456-43]

Navigational lights color study, Jose G. Barbosa, Naval Undersea Warfare Ctr. (USA) . . . . [9456-44]

Fundamentals of optical signal-based MWIR uncooled silicon carbide sensor for DoD/DHS applications, Geunsik Lim, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA). . . . . [9456-45]

Image processing in a maritime environment, Kenneth A. Pietrzak, Naval Undersea Warfare Ctr. (USA) . . . . [9456-46]

Submarine meteorological sensor, Jose G. Barbosa, Naval Undersea Warfare Ctr. (USA). . . . . [9456-47]

The transition from intelligence cycle to intelligence process: network-centric intelligence in narrow seas, Engin Büker, Turkish Naval War College (Turkey) . . . . [9456-48]

SESSION 12 . . . . WED 4:10 PM TO 5:30 PM

Infrastructure Protection: Air Operations

Session Chairs: **Tariq Manzur,** Naval Undersea Warfare Ctr. (USA); **Myron E. Hohil,** U.S. Army Armament Research, Development and Engineering Ctr. (USA)

The impact on air operations of ballistic missiles, Hasan Durak, Turkish Air Force Academy (Turkey) . . . . [9456-49]

Usage of turboprop aircrafts for counter terror missions, Eray Akin, Salim Oncu, Turkish Air War College (Turkey) . . . . [9456-50]

Human factor in future air command and control systems, Fatih Buyruk, Harun R. Altun, Ferhat Pinar, Turkish Air War College (Turkey) . . . . [9456-51]

Future's operation areas: new-generation suppression enemy air defence (SEAD) elements, Ilker Hazinedar, Yucel Canbolat, Turkish Air War College (Turkey) . . . . [9456-52]

CONFERENCE 9457

Wednesday 22 April 2015 • Proceedings of SPIE Vol. 9457

Biometric and Surveillance Technology for Human and Activity Identification XII

Conference Chairs: **Ioannis A. Kakadiaris,** Univ. of Houston (USA); **Ajay Kumar,** The Hong Kong Polytechnic Univ. (Hong Kong, China); **Walter J. Scheirer,** Harvard Univ. (USA)

Program Committee: **J. Ross Beveridge,** Colorado State Univ. (USA); **Christopher Bensing Boehnen,** Oak Ridge National Lab. (USA); **Terrance E. Boult,** Univ. of Colorado at Colorado Springs (USA); **Thirimachos Bourlai,** West Virginia Univ. (USA); **Rama Chellappa,** Univ. of Maryland, College Park (USA); **Bernadette Dorizzi,** TELECOM & Management SudParis (France); **Julian Fierrez,** Univ. Autónoma de Madrid (Spain); **Brian C. Heflin,** Univ. of Colorado at Colorado Springs (USA); **Daniel P. Lopresti,** Lehigh Univ. (USA); **Norman Poh,** Univ. of Surrey (United Kingdom); **Nalini K. Ratha,** IBM Thomas J. Watson Research Ctr. (USA); **Anderson Rocha,** Univ. Estadual de Campinas (Brazil); **Arun A. Ross,** Michigan State Univ. (USA); **Natalia A. Schmid,** West Virginia Univ. (USA); **Stephanie Schuckers,** Clarkson Univ. (USA); **William R. Schwartz,** UFMG (Brazil); **Shishir Shah,** Univ. of Houston (USA); **Kar-Ann Toh,** Yonsei Univ. (Korea, Republic of); **Raymond N. J. Veldhuis,** Univ. Twente (Netherlands); **Ruigang Yang,** Univ. of Kentucky (USA)

Wednesday 22 April

SESSION 1. . . . . WED 8:00 AM TO 9:00 AM

Biometric Privacy

Session Chair: **Walter J. Scheirer,** Harvard Univ. (USA)

Implementation and optimization of a biometric cryptosystem using iris recognition, Charles McGuffey, Chen Liu, Stephanie Schuckers, Clarkson Univ. (USA) . . . . [9457-1]

Fingerprint + Iris = IrisPrint, Asem A. Othman, Arun A. Ross, Michigan State Univ. (USA) . . . . [9457-2]

Identifying bitcoin users by transaction behavior, John V. Monaco, Pace Univ. (USA) . . . . [9457-3]

SESSION 2 . . . . WED 9:00 AM TO 10:00 AM

Human Behavior

Session Chair: **Ajay Kumar,**
The Hong Kong Polytechnic Univ. (Hong Kong, China)

Human actions recognition in confined spaces and under partial observability constraints, Amir Shirkhodaie, Tennessee State Univ. (USA); Alex L. Chan, Shuowen Hu, U.S. Army Research Lab. (USA). . . . . [9457-4]

Gait as a biometric using relevant features from biomechanics, Anthony H. Hawes, Jeffrey B. Flora, Khan M. Iftekharuddin, Old Dominion Univ. (USA) . . . . [9457-5]

Human task performance baseline: results from a cross-band facial identification perception study, Kenneth A. Byrd, Hee-Sue Choi, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9457-6]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 3 . . . . WED 1:00 PM TO 2:00 PM

Keynote Session

Session Chair: **Ioannis A. Kakadiaris,** Univ. of Houston (USA)

Keynote Presentaiton . . . . [9457-7]

SESSION 4 . . . . WED 2:00 PM TO 3:00 PM

Iris and Eye Movement

Session Chair: **Walter J. Scheirer,** Harvard Univ. (USA)

A gallery approach for off-angle iris recognition, Mahmut Karakaya, Rashiduddin Yoldash, Meliksah Univ. (Turkey) . . . . [9457-8]

Neurological disorder identification by eye movement biometric using machine learning schemes, Vivek Srivastava, Rama Univ. (India); Pipin K. Tripathi, Harcourt Butler Technological Institute (India). . . . . [9457-9]

An indexing method for color iris images, Simona G. Crihalmeanu, Arun A. Ross, Michigan State Univ. (USA) . . . . [9457-10]

SESSION 5 . . . . WED 3:30 PM TO 4:30 PM

Lightning Talk Session

Session Chair: **Ajay Kumar,**
The Hong Kong Polytechnic Univ. (Hong Kong, China)

Deep learning and face recognition: the state of the art, Stephen Balaban, Lambda Labs (USA) . . . . [9457-11]

Computational cameras for iris recognition, Scott McCloskey, Sharath Venkatesha, Honeywell Automation & Control Solutions (USA) [9457-12]

Privacy issues of biometric technologies in real-world applications, Emanuela Marasco, West Virginia Univ. (USA); Bojan Cukic, The Univ. of North Carolina at Charlotte (USA) . . . . [9457-13]

Anti-spoofing for display and print spoof attacks on palmprint verification systems, Vivek Kanhangad, Shruti Bhilare, Narendra S. Chaudhari, Indian Institute of Technology Indore (India) . . . . [9457-14]

Investigation of human behaviour using biometrics, Murugesh S. Subramani, Kalaimagal V., Meerasri M., Venkatesh C., EBET Group of Institutions (India). . . . . [9457-15]

Biometrics and IRB best practices, Christopher B Boehnen, Oak Ridge National Lab (USA); David Bolme, UT-Battelle (USA); Patrick Flynn, University of Notre Dame (USA). . . . . [9457-16]

SESSION 6 . . . . WED 4:30 PM TO 5:10 PM

Novel Modalities and Surveillance

Session Chair: **Ioannis A. Kakadiaris,** Univ. of Houston (USA)

Open-set speaker identification with diverse-duration speech data, Rawande Karadaghi, Heinz Hertlein, Aladdin M. Ariyaeeinia, Univ. of Hertfordshire (United Kingdom). . . . . [9457-17]

Multisensor concealed weapon detection using image fusion approach, Tuzhi Xu, Q. M. Jonathan Wu, Univ. of Windsor (Canada) . . . . [9457-18]

SESSION 7 . . . . WED 5:10 PM TO 5:50 PM

Emerging Perspectives in Bopmetrics

Session Chair: **Walter J. Scheirer,** Harvard Univ. (USA)

TBD, Ioannis A. Kakadiaris, Univ. of Houston (USA) . . . . [9457-19]

An automated watchlist identification system for higher security at the border crossings, Ajay Kumar, The Hong Kong Polytechnic University (Hong Kong, China) . . . . [9457-20]

CONFERENCE 9458

Tuesday 21 April 2015 • Proceedings of SPIE Vol. 9458

Cyber Sensing 2015

Conference Chairs: **Igor V. Ternovskiy,** Air Force Research Lab. (USA); **Peter Chin,** Draper Lab. (USA), Boston Univ. {United States)

Program Committee: **Chad D. Heitzenrater,** Air Force Research Lab. (USA); **Tony C. Kim,** Air Force Research Lab. (USA)

Tuesday 21 April

SESSION 1. . . . . TUE 8:00 AM TO 9:00 AM

Cyber Sensing I

Image reconstruction from sub-apertures of circular spotlight SAR, Xiaohui Yuan, Univ. of North Texas (USA); Igor V. Ternovskiy, Air Force Research Lab. (USA) . . . . [9458-1]

Testing simple deceptive honeypot tools, Aymen Yahyaoui, Tunisian Air Force (Tunisia); Neil C. Rowe, Naval Postgraduate School (USA) . . . . . . [9458-2]

A prototype forensic toolkit for industrial-control-systems incident response, Nickolas B Carr, U.S. Department of Homeland Security (USA); Neil C. Rowe, Naval Postgraduate School (USA). . . . . [9458-3]

SESSION 2 . . . . .TUE 9:00 AM TO 12:15 PM

Situation Awareness

Joint Session with Conferences 9458 and 9464

Session Chairs: **Igor V. Ternovskiy,** Air Force Research Lab. (USA); **Tien Pham,** U.S. Army Research Lab. (USA)

Situational consciousness for autonomous cyberspace operations *(Keynote Presentation)*, Steven K. Rogers, Air Force Research Lab. (USA). . . . . . . [9458-4]

Situational awareness: a holistic perspective your mother was afraid to tell you, Michael A Kolodny, U.S. Army Research Lab. (USA) . . . . [9464-18]

Qualia centric hypothetical thinking: applications to vehicle tracking with the fusion of EO and SAR input data sources *(Invited Paper)*, Jonathan L. White, Harding Univ. (USA); Anthony Helmstetter, Arizona State Univ. (USA); Jared L. Culbertson, Igor V. Ternovskiy, Air Force Research Lab. (USA) . [9458-5]

Automatic video-based classification of small group behavior to support situational understanding, Robert Williams, Air Force Research Lab. (USA); Julie A. Skipper, Skipper Consulting (USA). . . . . [9464-19]

Addressing cyber information overload with cognitive modeling constructs, Sandra L. Vaughan, Air Force Institute of Technology (USA) and U.S. Defense Intelligence Agency (USA); Robert F. Mills, Michael R. Grimaila, Gilbert L. Peterson, Air Force Institute of Technology (USA); Steven K. Rogers, Air Force Research Lab. (USA) . . . . [9458-6]

Why open system approaches matter, Kevin Priddy, U.S. Air Force Research Lab. (USA) . . . . [9464-20]

Lunch/Exhibition Break . . . . .12:15 pm to 1:45 pm

SESSION 3 . . . . TUE 1:45 PM TO 3:25 PM

Cyber Sensing II

On a simulation study for reliable and secured smart grid communication, Sriharsha Mallapuram, Paul Moulema, Wei Yu, Towson Univ. (USA) . . . . [9458-7]

Risk assessment by dynamic representation of vulnerability, exploitation, and impact, Hasan Cam, U.S. Army Research Lab. (USA) . . . . [9458-8]

Network traffic correlation using autonomous system number, Steve Hutchinson, ICF International (USA); Robert F. Erbacher, U.S. Army Research Lab. (USA) . . . . [9458-9]

CyberSecurity for aerospace autonomous systems, Jeremy Straub, Univ. of North Dakota (USA). . . . . [9458-10]

Cybercrime and prospect theory: Considerations for policy efforts and the framing of 'cyber warfare', Wesley Beaver, Oxford Internet Institute (United Kingdom) . . . . [9458-11]

SESSION 4 . . . . TUE 3:55 PM TO 5:15 PM

Cyber Sensing III

Is cyber warfare threat or advantage for air operations?, Harun R. Altun, Fatih Buyruk, Ferhat Pinar, Turkish Air War College (Turkey) . . . . [9458-12]

Turkey's cyber security perception and the portion of cyber security in national defence, Mahmut Tükenmez, Turkish Air Force Academy (Turkey) . . . . [9458-13]

Network systems security analysis, Ismail Yilmaz, Turkish Air Force Academy (Turkey) . . . . [9458-14]

Efficient non-resonant absorption of electromagnetic radiation in thin cylindrical targets: experimental demonstration , Andrey Akhmeteli, LTASolid Inc. (USA); Nikolay G. Kokodiy, Boris V. Safronov, Valeriy P. Balkashin, Ivan A. Priz, V.N. Karazin Kharkiv National Univ. (Ukraine); Alexander Tarasevitch, Univ. Duisburg-Essen (Germany) . . . . [9458-15]

CONFERENCE 9459

Tuesday–Wednesday 21–22 April 2015 • Proceedings of SPIE Vol. 9459

Ocean Sensing and Monitoring VII

Conference Chairs: **Weilin W. Hou,** U.S. Naval Research Lab. (USA); **Robert A. Arnone,** The Univ. of Southern Mississippi (USA)

Program Committee: **Samir Ahmed,** The City College of New York (USA); **James H. Churnside,** National Oceanic and Atmospheric Administration (USA); **Richard L. Crout,** U.S. Naval Research Lab. (USA); **Alexander Ignatov,** NOAA National Environmental Satellite, Data, and Information Service (USA); **Linda J. Mullen,** Naval Air Systems Command (USA); **Michael S. Twardowski,** WET Labs., Inc. (USA); **Brandon Cochenour,** Naval Air Warfare Ctr. Aircraft Div. (USA)

Tuesday 21 April

OPENING REMARKS. . . . . 8:00 AM TO 8:10 AM

Session Chairs: **Weilin W. Hou,** U.S. Naval Research Lab. (USA); **Robert A. Arnone,** The Univ. of Southern Mississippi (USA)

SESSION 1. . . . . TUE 8:10 AM TO 10:20 AM

Free Space Optical Communications Underwater

Session Chair: **Brandon Cochenour,** Naval Air Warfare Ctr. Aircraft Div. (USA)

An overview of underwater blue-green optical communications *(Invited Paper)*, Greg Mooradian, Mooradian & Associates, Inc. (USA); Michael Lovern, Space and Naval Warfare Systems Ctr. Pacific (USA). . . . . [9459-1]

Common underwater free space optical (UFSO) communications architectures in support of both defense and oil and gas applications, Greg Mooradian, Mooradian & Associates, Inc. (USA) and Leidos (USA); Dean Richter, Sonalysts, Inc. (USA); Susan Harris, Leidos (USA); Stephen Szender, Liedos, Inc. (USA). . . . . [9459-2]

High bandwidth underwater optical communications: overview and practical applications, Norman E. Farr, Woods Hole Oceanographic Institution (USA) . . . . [9459-3]

Spatial multiplexing for blue lasers for undersea communications, Joshua Baghdady, Matthew Byrd, Wenzhe Li, Kaitlyn Morgan, Aaron Páng, Eric Johnson, Clemson Univ. (USA) . . . . [9459-4]

High-speed blue-light free space optical receiver, Susan Harris, Mark Krepel, Leidos (USA); Greg Mooradian, Mooradian & Associates, Inc. (USA) and Leidos (USA) . . . . [9459-5]

Airborne relay connectivity through air/ice/water interface comm (ARCTIComm) high data rate through-ice optical communication system, Dean Richter, Sonalysts, Inc. (USA); Greg Mooradian, Mooradian & Associates, Inc. (USA); Susan Harris, Stephen Szender, Leidos (USA) . . . . [9459-6]

SESSION 2 . . . . TUE 10:50 AM TO 12:30 PM

Characterization for Underwater Optical Communications

Session Chair: **Brandon Cochenour,** Naval Air Warfare Ctr. Aircraft Div. (USA)

Underwater-detector array for laser beam diagnostics, Shachak Pe'eri, Firat Eren, The Univ. of New Hampshire (USA); Jack L. Riley, National Oceanic and Atmospheric Administration (USA); May-Win Thein, Yuri Rzhanov, Matthew Birkebak, The Univ. of New Hampshire (USA) . . . . [9459-7]

Chaotic lidar for underwater channel identification, Luke K. Rumbaugh, David W. Illig, William D. Jemison, Clarkson Univ. (USA) . . . . [9459-8]

Experimental validation of a Monte Carlo model for determining the temporal response of the underwater optical communications channel, Alan Laux, Brandon Cochenour, Naval Air Warfare Ctr. Aircraft Div. (USA) . . . . . . [9459-9]

Monte Carlo model for time-dependent LIDAR return from complex 3D targets with photon path dispersion effects, Anthony Kellems, Thomas E. Giddings, Joseph J. Shirron, Metron, Inc. (USA); Linda J. Mullen, Brandon Cochenour, Derek M. Alley, Alan Laux, Robert W. Lee, Naval Air Systems Command (USA) . . . . [9459-10]

Use of polarimetric imaging for discriminating oil from water, Amber Iler, Patrick Hamilton, Integrity Applications, Inc. (USA) . . . . [9459-11]

Lunch/Exhibition Break . . . . Tue 12:30 pm to 2:00 pm

SESSION 3 . . . . TUE 2:00 PM TO 3:20 PM

Underwater Optical Imaging and Ranging

Session Chair: **Linda J. Mullen,** Naval Air Systems Command (USA)

FMCW optical ranging technique in turbid waters, David W. Illig, William D. Jemison, Clarkson Univ. (USA); Robert W. Lee, Alan Laux, Linda J. Mullen, Naval Air Systems Command (USA) . . . . [9459-12]

Pulse compression techniques to improve modulated pulsed laser line scan systems, Robert W. Lee, Naval Air Systems Command (USA) and Univ. of Maryland (USA); Linda J. Mullen, Shawn P. O'Connor, Brandon Cochenour, Naval Air Systems Command (USA) . . . . [9459-13]

DCS versus DCS: evaluation of different signal models for the underwater compressive line sensing imaging system, Bing Ouyang, Harbor Branch Oceanographic Institute (USA); Weilin W. Hou, U.S. Naval Research Lab. (USA); Frank M. Caimi, Fraser R. Dalgleish, Anni K. Vuorenkoski, Harbor Branch Oceanographic Institute (USA); Cuiling Gong, Texas Christian Univ. (USA) . . . . [9459-14]

Semi-empirical inversion technique for retrieval of quantitative attenuation profiles with underwater scanning LIDAR systems, Anni K. Vuorenkoski, Fraser R. Dalgleish, Harbor Branch Oceanographic Institute (USA); Michael S. Twardowski, WET Labs., Inc. (USA); Bing Ouyang, Harbor Branch Oceanographic Institute (USA); Charles C. Trees, STO-CMRE (Italy). . . [9459-15]

SESSION 4 . . . . .TUE 3:50 PM TO 5:10 PM

Underwater Optical Imaging and Ranging II

Session Chair: **Weilin W. Hou,** U.S. Naval Research Lab. (USA)

Analysis of polarimetric image by full stokes vector imaging camera for retrieval of target polarization in underwater environment, Yalong Gu, Carlos Carrizo, Ahmed El-Habashi, Alexander Gilerson, The City College of New York (USA). . . . . [9459-16]

The influence of the choice of the phase function on imaging under water, Katrin Braesicke, Endre Repasi, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany). . . . . [9459-17]

A controlled laboratory environment to study EO signal degradation due to underwater turbulence, Silvia C. Matt, Weilin W. Hou, Wesley Goode, Andrey V. Kanaev, Sergio R. Restaino, U.S. Naval Research Lab. (USA) . . . . . . [9459-18]

A miniature fiber-optic sensor for high-resolution and high-speed temperature and flow sensing in ocean environment, Ming Han, Univ. of Nebraska-Lincoln (USA); Weilin W. Hou, U.S. Naval Research Lab. (USA); Guigen Liu, Univ. of Nebraska-Lincoln (USA) . . . . [9459-19]

Wednesday 22 April

SESSION 5 . . . . WED 8:30 AM TO 10:30 AM

Ocean Observations and Models

Session Chair: **Robert A. Arnone,** The Univ. of Southern Mississippi (USA)

An expansion of glider observation strategies to systematically transmit and analyze preferred waypoints of underwater gliders, Lucy F. Smedstad, Charlie N. Barron, U.S. Naval Research Lab. (USA); Michael W. Brooking, Danielle A. Bryant, Naval Oceanographic Office (USA); Robert J. Carr, Univ. of Washington (USA); Kevin D. Henaey, Ocean Acoustical Services and Instrumentation Systems, Inc. (USA); Edward A. Holmberg, Univ. of New Orleans (USA); Andrea C. Mask, Bryan L. Mensi, Naval Oceanographic Office (USA) . . . . [9459-20]

Are the satellite-observed narrow, streaky chlorophyll filaments locally intensified by the submesoscale processes?, Igor Shulman, Bradley Penta, James G. Richman, Gregg Jacobs, Stephanie Anderson, Peter Sakalaukus, U.S. Naval Research Lab. (USA) . . . . [9459-21]

Factors affecting radiometric calibration of ocean color satellite sensors using AERONET-OC data, Samir Ahmed, Vincius De Paula, Alexander Gilerson, The City College of New York (USA); Menghua Wang, NOAA National Environmental Satellite, Data, and Information Service (USA); Robert A. Arnone, The Univ. of Southern Mississippi (USA) . . . . [9459-22]

Bio-optical model of remote sensing signals in a stratified ocean, James H. Churnside, National Oceanic and Atmospheric Administration (USA) . . . . [9459-23]

Ocean and polarization observations from active remote sensing: atmospheric and ocean science applications, Damien B. Josset, Weilin W. Hou, U.S. Naval Research Lab. (USA); Jacques R. Pelon, Univ. Pierre et Marie Curie (France); Yongxiang Hu, NASA Langley Research Ctr. (USA); Simone Tanelli, Jet Propulsion Lab. (USA); Richard Ferrare, Sharon P. Burton, NASA Langley Research Ctr. (USA); Nicolas Pascal, Univ. des Sciences et Technologies de Lille (France) . . . . [9459-24]

Real-time ship monitoring system for offshore maritime surveillance in South Korea, Chan-Su Yang, Korea Institute of Ocean Science & Technology (Korea, Republic of) . . . . [9459-25]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:30 AM TO 1:30 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 6 . . . . WED 1:30 PM TO 3:10 PM

Sea Surface Temperature Remote Sensing I

Session Chair: **Alexander Ignatov,** NOAA National Environmental Satellite, Data, and Information Service (USA)

Ocean thermal fronts detection in the full thermal IR imagery, Irina Gladkova, The City College of New York (USA) and NOAA-CREST (USA); Fazlul Shahriar, The City College of New York (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA); Yury Kihai, NOAA National Environmental Satellite, Data, and Information Service (USA) and GST, Inc. (USA) . . . . [9459-26]

A fast, robust, adaptive destriping algorithm for SNPP VIIRS and Terra/Aqua MODIS SST, Karlis Mikelsons, GST, Inc. (USA) and NOAA National Environmental Satellite, Data, and Information Service (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA); Marouan Bouali, Univ. de São Paulo (Brazil); Yury Kihai, GST, Inc. (USA) and NOAA National Environmental Satellite, Data, and Information Service (USA) . . . . [9459-27]

Evaluation of VIIRS SST fields through the analysis of overlap regions between consecutive orbits, Jean-François P. Cayula, Vencore, Inc. (USA) . . . . [9459-28]

Seasonal trends of ocean SST products characterized by the differences in orbital overlaps for waters types, Robert A. Arnone, Ryan A. Vandermeulen, The Univ. of Southern Mississippi (USA); Jean-François P. Cayula, Vencore, Inc. (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA) . . . . [9459-29]

Suppressing the noise in SST retrieved from satellite infrared measurements by smoothing the differential terms in regression equations, Boris Petrenko, NOAA National Environmental Satellite, Data, and Information Service (USA) and GST, Inc. (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA); Yury Kihai, NOAA National Environmental Satellite, Data, and Information Service (USA) and GST, Inc. (USA) . . . . [9459-30]

SESSION 7 . . . . WED 3:40 PM TO 5:40 PM

Sea Surface Temperature Remote Sensing II

Session Chairs: **Robert A. Arnone,** The Univ. of Southern Mississippi (USA); **Jean-François Paul Cayula,** Vencore, Inc. (USA)

VIIRS SST products and monitoring at NOAA, Alexander Ignatov, John Stroup, Yury Kihai, Boris Petrenko, Irina Gladkova, Prasanjit Dash, Xingming Liang, Feng Xu, Xinjia Zhou, Karlis Mikelsons, John Sapper, NOAA National Environmental Satellite, Data, and Information Service (USA) . [9459-31]

Monitoring and validation of AVHRR FRAC, MODIS, (A)ATSR and VIIRS high-resolution sea surface temperatures, Prasanjit Dash, Alexander Ignatov, Yury Kihai, John Stroup, Boris Petrenko, John Sapper, NOAA National Environmental Satellite, Data, and Information Service (USA) . . . . [9459-32]

Assimilation of ECMWF versus GFS profiles in fast CRTM for SST retrievals at NOAA, Xingming Liang, NOAA National Environmental Satellite, Data, and Information Service (USA) and Colorado State Univ. (USA) and Cooperative Institute for Research in the Atmosphere (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA) . [9459-33]

A new deterministic inversion technique for sea surface temperature retrieval from MODIS radiances, Prabhat K. Koner, Andrew R. Harris, The Univ. of Maryland (USA) . . . . [9459-34]

Long-term analysis of AVHRR calibration in thermal IR channels, Kai He, GST, Inc. (USA) and NOAA National Environmental Satellite, Data, and Information Service (USA); Alexander Ignatov, NOAA National Environmental Satellite, Data, and Information Service (USA); Yury Kihai, GST, Inc. (USA) and NOAA National Environmental Satellite, Data, and Information Service (USA); Xingming Liang, NOAA National Environmental Satellite, Data, and Information Service (USA) and Colorado State Univ. (USA); Changyong Cao, NOAA National Environmental Satellite, Data, and Information Service (USA); John Stroup, NOAA National Environmental Satellite, Data, and Information Service (USA) and Stinger Ghaffarian Technologies (USA) . . . . [9459-35]

A statistical methodology to identify stable/instable areas from remote sensing and numerical ocean models, Jesus Loeches, STO-CMRE (Italy); Raul Vicen, North Atlantic Treaty Organization (Italy) and STO-CMRE (Italy); Giuliana Pennucci, Aniello Russo, STO-CMRE (Italy) . . . . [9459-36]

CONFERENCE 9460

Monday–Tuesday 20–21 April 2015 • Part of Proceedings of SPIE Vol. 9460

Airborne Intelligence, Surveillance, Reconnaissance (ISR) Systems and Applications XII

Conference Chair: **Daniel J. Henry,** Rockwell Collins, Inc. (USA)

Conference Co-Chairs: **Gregory J. Gosian,** L-3 Communications (USA); **Davis A. Lange,** UTC Aerospace Systems (USA); **Dale Linne von Berg,** U.S. Naval Research Lab. (USA); **Thomas J. Walls,** U.S. Naval Research Lab. (USA); **Darrell L. Young,** Raytheon Intelligence & Information Systems (USA)

Monday 20 April

SESSION 1. . . . . .MON 9:00 AM TO 10:00 AM

ISR: Vision, Mission, and Tactics

Session Chair: **Dale Linne von Berg,** U.S. Naval Research Lab. (USA)

Reconnaissance architecture in near space, Eren O. Dundar, Harp Akademileri Komutanlığı (Turkey) . . . . [9460-1]

Hybrid consensus UAV formation control, Haci Mehmet Guzey, Missouri Univ. of Science and Technology (USA); Travis A. Dierks, DRS Sustainment Systems, Inc. (USA); Jagannathan Sarangapani, Missouri Univ. of Science and Technology (USA) . . . . [9460-2]

Design of a disguised miniature unmanned aerial vehicle (UAV) system with surveillance function, Terence K. L. Goh, Donny Ng, Ian V. H. Tam, SIM Univ. (Singapore) . . . . [9460-3]

SESSION 2 . . . . MON 10:30 AM TO 12:10 PM

ISR: Passive and Active Sensing

Session Chair: **Thomas J. Walls,** U.S. Naval Research Lab. (USA)

IR CMOS: an ISR solution for Nightvision and See Spot, Martin U. Pralle, James E. Carey, Chris J. Vineis, SiOnyx Inc. (USA) . . . . [9460-4]

Results from an experiment that collected visible-light polarization data using unresolved imagery for classification of geosynchronous satellites, Andy Speicher, Mohammad A. Matin, Univ. of Denver (USA); Francis K. Chun, Roger D. Tippets, U.S. Air Force Academy (USA). . . . . [9460-5]

Laser links for mobile airborne nodes, Wolfgang Griethe, G2Aerospace GmbH (Germany); Markus Knapek, Joachin Horwath, ViaLight Communications GmbH (Germany). . . . . [9460-6]

Small SWAP 3D flash ladar for small tactical unmanned air systems, Alan W. Bird, Scott A. Anderson, Michael D. Wojcik, Scott E. Budge, Utah State Univ. (USA) . . . . [9460-7]

EM modeling of far-field radiation patterns for antennas on the GMA-TT UAV, Anne I Mackenzie, NASA Langley Research Center (USA) . . . . [9460-8]

Lunch Break . . . . .Mon 12:10 pm to 1:40 pm

SESSION 3 . . . . .MON 1:40 PM TO 3:00 PM

ISR: Image Fusion/Enhancement

Session Chair: **Davis A. Lange,** UTC Aerospace Systems (USA)

Fusion of infrared and optical aerial images, Ali E. Destegül, Turkish Armed Forces (Turkey) . . . . [9460-9]

Fusion of video and radar comparison to 3D ladar for activity recognition, David Tahmoush, U.S. Army Research Lab. (USA). . . . . [9460-10]

Real-time embedded technology for enhancing long-range imagery, Aaron L. Paolini, Daniel L. Hertenstein, EM Photonics, Inc. (USA) and EM Photonics, Inc. (USA); Eric J. Kelmelis, James Bonnett, Paul A. Fox, EM Photonics, Inc. (USA) . . . . [9460-11]

Characterization of UAV hover patterns in support of superresolution research, Jeremy Straub, Ronald Marsh, Univ. of North Dakota (USA). [9460-12]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 4 . . . . TUE 8:20 AM TO 9:20 AM

ISR: Image Processing and Tracking

Session Chair: **Gregory J. Gosian,** L-3 Communications (USA)

Aerial video mosaicking using binary feature tracking, Breton L. Minnehan, Andreas E. Savakis, Rochester Institute of Technology (USA) . . . . [9460-13]

Background image understanding and adaptive imaging for vehicle tracking, Anthony Vodacek, Matthew J. Hoffman, Burak Uzkent, Bin Chen, Rochester Institute of Technology (USA) . . . . [9460-14]

Enhanced performance for the interacting multiple model estimator with integrated multiple filters, Madeleine G. Sabordo, Elias Aboutanios, The Univ. of New South Wales (Australia) . . . . [9460-15]

SESSION 5 . . . . .TUE 9:20 AM TO 10:00 AM

ISR: Change Detection

Session Chair: **Gregory J. Gosian,** L-3 Communications (USA)

Improving change detection results with knowledge of registration uncertainty, Andrew J. Lingg, Etegent Technologies, Ltd. (USA); Brian D. Rigling, Wright State Univ. (USA) . . . . [9460-16]

Change detection on UGV patrols with respect to a reference tour using VIS imagery, Thomas Müller, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany). . . . . [9460-17]

CONFERENCE 9460

SESSION 6 . . . . TUE 10:30 AM TO 11:10 AM

ISR: Exploitation

Session Chair: **Darrell L. Young,**
Raytheon Intelligence & Information Systems (USA)

Pressing the sparsity advantage via data-based decomposition, Vahid R. Riasati, Raytheon Space & Airborne Systems (USA) . . . . [9460-18]

Orthomosaic construction and analysis of EO imagery from a small unmanned aircraft system (SUAS) for natural resources management on an active military training range, Leslie Bolick, Nicholas C. Stroumtsos, Dawn Lawson, Kimberly O'Connor, SPAWAR Systems Ctr. (USA) . . . . [9460-19]

SESSION 7 . . . . TUE 11:10 AM TO 12:10 PM

ISR: Image Sequences/Full Motion Video

Session Chair: **Darrell L. Young,**
Raytheon Intelligence & Information Systems (USA)

Image sequence exploitation for mobile operations, Markus Mueller, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany); Stella Oldenbuerger, Bundeswehr Technical Ctr. for Information Technology and Electronics (Germany) . . . . [9460-20]

Context and quality estimation in video for enhanced event detection, John M. Irvine, Richard J. Wood, Draper Lab. (USA). [9460-21]

Automated FMV image quality assessment based on power spectrum statistics, Andrew R. Kalukin, NGA/IID (USA) . . . . [9460-22]

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www.spie.org/dss15program

CONFERENCE 9461A

Monday–Wednesday 20–22 April 2015 • Part of Proceedings of SPIE Vol. 9461

Radar Sensor Technology XIX

Conference Chairs: **Kenneth I. Ranney,** U.S. Army Research Lab. (USA); **Armin Doerry,** Sandia National Labs. (USA)

Program Committee: **Fauzia Ahmad,** Villanova Univ. (USA); **Moeness G. Amin,** Villanova Univ. (USA); **Joseph C. Deroba,** U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); **Mark Govoni,** U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); **Majeed Hayat,** The Univ. of New Mexico (USA); **Chandra Kambhamettu,** Univ. of Delaware (USA); **Seong-Hwoon Kim,** Raytheon Space & Airborne Systems (USA); **James L. Kurtz,** Univ. of Florida (USA); **Changzhi Li,** Texas Tech Univ. (USA); **Jenshan Lin,** Univ. of Florida (USA); **Hao Ling,** The Univ. of Texas at Austin (USA); **David G. Long,** Brigham Young Univ. (USA); **Jia-Jih Lu,** General Atomics Aeronautical Systems, Inc. (USA); **Neeraj Magotra,** Western New England Univ. (USA); **Anthony F. Martone,** U.S. Army Research Lab. (USA); **Gregory J. Mazzaro,** The Citadel (USA); **George J. Moussally,** Mirage Systems (USA); **Ram M. Narayanan,** The Pennsylvania State Univ. (USA); **Lam H. Nguyen,** U.S. Army Research Lab. (USA); **Hector A. Ochoa,** The Univ. of Texas at Tyler (USA); **Zhijun G. Qiao,** The Univ. of Texas-Pan American (USA); **Ann M. Raynal,** Sandia National Labs. (USA); **Jerry Silvious,** U.S. Army Research Lab. (USA); **Brian Smith,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Helmut Suess,** Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); **David Tahmoush,** U.S. Army Research Lab. (USA); **Russell Vela,** Air Force Research Lab. (USA); **Berenice Verdin,** The Univ. of Texas at El Paso (USA); **Frank Yakos,** SELEX Galileo, Inc. (USA); **Yan Zhang,** The Univ. of Oklahoma (USA)

MONDAY 20 APRIL

OPENING REMARKS . . . . 8:20 AM TO 8:30 AM

Session Chairs: **Armin W. Doerry,** Sandia National Labs. (USA); **Kenneth I. Ranney,** U.S. Army Research Lab. (USA)

SESSION 1. . . . . MON 8:30 AM TO 10:30 AM

Components and Technologies

Session Chair: **Ann M. Raynal,** Sandia National Labs. (USA)

Calculation of the phase-center offset from 2D antenna radiation patterns, Patrick S. Deboux, Berenice Verdin, U.S. Army Research Lab. (USA); Samuel A. Pichardo, The Univ. of Texas at El Paso (USA). . . . . [9461-1]

Characterization of radar cross section of carbon-fiber composite materials, Elliot J. Riley, Erik H. Lenzing, Ram M. Narayanan, The Pennsylvania State Univ. (USA). . . . . [9461-2]

Design considerations for eye-safe single-aperture laser radars, Dmitry S. Starodubov, Torrey Pines Logic, Inc. (USA) . . . . [9461-3]

Deployment of rare Earth elements (REEs) on RF sources, lasers, and EO/IR sensors, Asu R. Jha, JHA Technical Consulting Services (USA) . [9461-4]

System-on-chip architecture and validation for real-time transceiver optimization, Hernan Suarez, Yan Zhang, The Univ. of Oklahoma (USA) . . . . [9461-5]

Acceleration of generalized adaptive pulse compression with parallel GPUs, Jingxiao Cai, Yan R. Zhang, The Univ. of Oklahoma (USA) . . . . . [9461-6]

SESSION 2 . . . . MON 11:00 AM TO 12:20 PM

Non-Linear and Cognitive Radar

Session Chairs: **Gregory J. Mazzaro,** The Citadel (USA); **Anthony F. Martone,** U.S. Army Research Lab. (USA)

Short-range harmonic radar: chirp waveform, electronic targets, Gregory J. Mazzaro, The Citadel (USA); Kyle A. Gallagher, The Pennsylvania State Univ. (USA); Anthony F. Martone, Kelly D. Sherbondy, U.S. Army Research Lab. (USA); Ram M. Narayanan, The Pennsylvania State Univ. (USA) . . . . [9461-7]

Nonlinear synthetic aperture radar imaging using a harmonic radar, Kyle A. Gallagher, The Pennsylvania State Univ. (USA); Gregory J. Mazzaro, The Citadel (USA); Kenneth I. Ranney, Lam H. Nguyen, Anthony F. Martone, Kelly D. Sherbondy, U.S. Army Research Lab. (USA); Ram M. Narayanan, The Pennsylvania State Univ. (USA). . . . . [9461-8]

Filter selection for a harmonic radar receiver, Kyle A. Gallagher, The Pennsylvania State Univ. (USA); Gregory J. Mazzaro, The Citadel (USA); Anthony F. Martone, Kelly D. Sherbondy, U.S. Army Research Lab. (USA); Ram M. Narayanan, The Pennsylvania State Univ. (USA). . . . . [9461-9]

Sparse SAR imaging for stepped frequency nonlinear radar, Lam H. Nguyen, U.S. Army Research Lab. (USA); Kyle A. Gallagher, The Pennsylvania State Univ. (USA); Kenneth I. Ranney, U.S. Army Research Lab. (USA) . . . . [9461-10]

Lunch Break . . . . .Mon 12:20 pm to 1:30 pm

SESSION 3 . . . . MON 1:30 PM TO 3:10 PM

Algorithms and Phenomenology I

Session Chair: **Mark A. Govoni,** U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA)

Terrain clutter simulation using physics-based scattering model and digital terrain profile data, James Park, Air Force Research Lab. (USA); Joel T. Johnson, The Ohio State Univ. (USA); Kung-Hau Ding, Kristopher Kim, Joseph Tenbarge, Air Force Research Lab. (USA) . . . . [9461-11]

Radar-centric scattering of possible targets for orbital debris remediation, Russell Vela, James Park, Brian M. Kent, Air Force Research Lab. (USA); Anthony Griffith, Rebecca Johanning, Kenneth Baker, Peter Spehar, NASA Johnson Space Ctr. (USA) . . . . [9461-12]

The Born approximation, multiple scattering, and algorithm, Alejandro F. Martinez, Zhijun G. Qiao, The Univ. of Texas-Pan American (USA) . . . . [9461-13]

Building detection in SAR imagery, Ryan M. Steinbach, Mark W. Koch, Mary M. Moya, Jeremy Goold, Sandia National Labs. (USA). . . . . [9461-14]

Automatic segmentation of ice layers in radar images, Maryam Rahnemoonfar, Texas A&M Univ. Corpus Christi (USA) . . . . [9461-15]

SESSION 4 . . . . MON 3:40 PM TO 4:40 PM

Indoor/Urban Target Detection, Localization, and Tracking

Session Chair: **Fauzia Ahmad,** Villanova Univ. (USA)

Bistatic and multistatic target identification for through-wall radar imaging, Joshua M. Allebach, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Benjamin Hoe, DSCI (USA); Sean P. Broderick, U.S. Army RDECOM CERDEC NVESD (USA). . . . . [9461-16]

Fall detection and classification though walls and in heavy indoor clutter, Moeness G. Amin, Fauzia Ahmad, Villanova Univ. (USA) . . . . [9461-17]

RCS information theoretic approach for target classification, Travis D. Bufler, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Traian V. Dogaru, U.S. Army Research Lab. (USA) . . . . [9461-18]

TUESDAY 21 APRIL

SESSION 5 . . . . TUE 8:00 AM TO 10:00 AM

Programs and Applications

Session Chairs: **Jerry L. Silvious,** U.S. Army Research Lab. (USA); **Seong-Hwoon Kim,** Raytheon Space & Airborne Systems (USA)

Performance analysis of spectrally versatile forward-looking ground-penetrating radar for detection of concealed targets, Brian R. Phelan, The Pennsylvania State Univ. (USA); Marc A. Ressler, Kenneth I. Ranney, Gregory D. Smith, Getachew A. Kirose, Kelly D. Sherbondy, U.S. Army Research Lab. (USA); Ram M. Narayanan, The Pennsylvania State Univ. (USA) . . . . . . [9461-19]

FlexSAR: demonstrating high-quality, cost-effective multimodal radar system prototyping, Mark D. Jensen, Chad Knight, Space Dynamics Lab. (USA) . . . . [9461-20]

Recent experiments using the ARL Rail-SAR, Kenneth I. Ranney, U.S. Army Research Lab. (USA); Brian R. Phelan, The Pennsylvania State Univ. (USA); Getachew A. Kirose, Kelly D. Sherbondy, U.S. Army Research Lab. (USA) . . . . [9461-21]

Technology integration and synergies: radar, optics, and AIS, Hasan Shahid, Stevens Institute of Technology (USA); Joe Nathan Abellard, New York City College of Technology (USA); Yong-Qi Chen, Stevens Institute of Technology (USA); David M. González Chévere, Univ. de Puerto Rico Mayagüez (USA) . . . . [9461-22]

Radom effects on coherent change detection radar systems, Ann M. Raynal, Dale F. Dubbert, Bryan L. Burns, William H. Hensley Jr., Sandia National Labs. (USA) . . . . [9461-23]

SAR-based vibrometry using the fractional Fourier transform, Majeed M. Hayat, The Univ. of New Mexico (USA); Tom D. Atwood, Sandia National Labs. (USA); Justin B. Campbell, Jelili Ade-bello, Ishwor Bhatta, Humberto Caudana, Nicole B. Trujillo, Balu Santhanam, Walter H. Gerstle, The Univ. of New Mexico (USA); Armin W. Doerry, Sandia National Labs. (USA) . . . . [9461-24]

SESSION 6 . . . . TUE 10:30 AM TO 12:10 PM

Algorithms and Phenomenology

Session Chair: **Lam H. Nguyen,** U.S. Army Research Lab. (USA)

An algorithm for segmenting polarimetric SAR imagery, Jorge V. Geaga, Consultant (USA) . . . . [9461-25]

Generalization of susceptibility of RF systems through far-field pattern superposition, Berenice Verdin, Patrick S. Debroux, U.S. Army Research Lab. (USA) . . . . [9461-26]

A practical look at target detection using MIMO radar, Mark A. Govoni, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); Jeffrey Spak, U.S. Army Communications-Electronics Research Development and Engineering Command (USA); Traian V. Dogaru, DaHan Liao, U.S. Army Research Lab. (USA) . . . . [9461-27]

Sensor fusion in RF tomography of stationary objects in free space: preliminary results, Jia Li, Oakland Univ. (USA); Robert L. Ewing, Charles Berdanier, Air Force Research Lab. (USA); Chris J. Baker, The Ohio State Univ. (USA) . . . . [9461-28]

Application of equalization notch to improve synthetic aperture radar coherent data products, Cameron Musgrove, Sandia National Labs. (USA); James C. West, Oklahoma State Univ. (USA) . . . . [9461-29]

Lunch/Exhibition Break . . . . Tue 12:10 pm to 1:20 pm

SESSION 7 . . . . TUE 1:20 PM TO 3:00 PM

Noise and LPI Radar I

Session Chair: **Yan Rockee Zhang,** The Univ. of Oklahoma (USA)

Radar cross-sectional study using noise radar, Al Freundorfer, Queen's Univ. (Canada); Jawad Y. Siddiqui, Yahia M. Antar, Royal Military College of Canada (Canada) . . . . [9461-30]

Principle and experimental results of ultra-wideband noise radar imaging of a cylindrical conducting object using diffraction tomography, Hee Jung Shin, Mark A. Asmuth, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Muralidhar Rangaswamy, Air Force Research Lab. (USA) . . . . [9461-31]

Design and implementation of a noise radar tomographic system, Mark A. Asmuth, Hee Jung Shin, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Muralidhar Rangaswamy, Air Force Research Lab. (USA) . [9461-32]

Efficient pulse compression for LPI waveforms based on a nonparametric iterative adaptive approach, Zhengzheng Li, The Univ. of Oklahoma (USA); Shang Wang, RFMD (USA); Yan Zhang, The Univ. of Oklahoma (USA) . [9461-33]

Probability of target detection using advanced pulse compression noise (APCN), Mark A. Govoni, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); Ryan A. Elwell, U.S. Army Communications-Electronics Research Development and Engineering Command (USA); Traian V. Dogaru, DaHan Liao, U.S. Army Research Lab. (USA) . . . . [9461-34]

SESSION 8 . . . . TUE 3:30 PM TO 4:10 PM

Noise and LPI Radar II

Session Chair: **Mark A. Govoni,** U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA)

Analysis of chaotic system synchronization for bistatic radar, Chandra S. Pappu, The Univ. of Texas at El Paso (USA); Berenice Verdin, U.S. Army Research Lab. (USA); Benjamin C. Flores, The Univ. of Texas at El Paso (USA); James Boehm, Patrick S. Debroux, U.S. Army Research Lab. (USA) . . [9461-35]

The implementation of compressive sensing on an FPGA for chaotic radars, Hector A. Ochoa, The Univ. of Texas at Tyler (USA); David H. Hoe, Loyola Univ. Maryland (USA); Dinesh Veeramachaneni, The Univ. of Texas at Tyler (USA). . . . . [9461-36]

SESSION 9 . . . . TUE 4:10 PM TO 5:50 PM

Quantum Radar

Session Chair: **Marco O. Lanzagorta,** U.S. Naval Research Lab. (USA)

Range detection using entangled optical photons, Matthew J. Brandsema, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Marco O. Lanzagorta, U.S. Naval Research Lab. (USA) . . . . [9461-37]

Algorithmic analysis of quantum radar sidelobes, Salvador E. Venegas-Andraca, Tecnológico de Monterrey (Mexico); Marco O. Lanzagorta, U.S. Naval Research Lab. (USA) . . . . [9461-38]

Low-brightness quantum radar, Marco O. Lanzagorta, U.S. Naval Research Lab. (USA) . . . . [9461-39]

Quantum error reduction without coding, Keye Martin, U.S. Naval Research Lab. (USA) . . . . [9461-40]

Space-based quantum sensing for detection of small targets, Jeffrey K. Uhlmann, George Mason Univ. (USA); Marco O. Lanzagorta, U.S. Naval Research Lab. (USA) . . . . [9461-41]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. . . . . TUE 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Spurious effects of analog-to-digital conversion nonlinearities on radar range-Doppler maps, Armin W. Doerry, Dale F. Dubbert, Bert L. Tise, Sandia National Labs. (USA) . . . . [9461-49]

Balancing radar receiver channels with commutation, Armin W. Doerry, Sandia National Labs. (USA) . . . . [9461-50]

Comments on radar interference sources and mitigation techniques, Armin W. Doerry, Sandia National Labs. (USA) . . . . [9461-51]

Balancing I/Q data in radar range-Doppler images, Armin W. Doerry, Sandia National Labs. (USA) . . . . [9461-52]

Joint estimation of thermal and multiplicative noise levels in dual- and quad-polarization SAR images, Robert Riley, Sandia National Labs. (USA) . . . . [9461-53]

Experimental evaluation of single-aperture range finder, Kyle McCormick, Dmitry S. Starodubov, Leo Volfson, Torrey Pines Logic, Inc. (USA) . . . . [9461-54]

Coherence model for building layover in interferometric SAR, Douglas L Bickel, Sandia National Labs. (USA) . . . . [9461-55]

WEDNESDAY 22 APRIL

SESSION 10 . . . . WED 9:00 AM TO 10:20 AM

Medical Applications of Radar

Session Chair: **Ram M. Narayanan,** The Pennsylvania State Univ. (USA)

Investigations on the effect of frequency and noise in a localization technique based on microwave imaging for an in-body RF-source, Rohit Chandra, Norwegian Univ. of Science and Technology (Norway); Ilangko Balasingham, Norwegian Univ. of Science and Technology (Norway) and Oslo Univ. Hospital (Norway) . . . . [9461-42]

A new microwave imaging algorithm based on third-generation WCE system, Huiyuan Zhou, The Pennsylvania State Univ. (USA); Rohit Chandra, Norwegian Univ. of Science and Technology (Norway); Ilangko Balasingham, Oslo Univ. Hospital (Norway); Ram M. Narayanan, The Pennsylvania State Univ. (USA) . . . . [9461-43]

Investigating signatures of diverse waveforms to assess changes in thickness and dielectric properties of intestines afflicted with Crohn's disease, Sonny Smith, Ram M. Narayanan, The Pennsylvania State Univ. (USA); Evangelos Messaris, Penn State Milton S. Hershey Medical Ctr. (USA). [9461-44]

Radar sensitivity to human heartbeats and respiration, Øyvind Aardal, Sverre Brovoll, Yoann Paichard, Tor Berger, Norwegian Defence Research Establishment (Norway); Tor Sverre Lande, Univ. I Oslo (Norway); Svein-Erik Hamran, Norwegian Defence Research Establishment (Norway) and Univ. I Oslo (Norway) . . . . [9461-45]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:20 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 11. . . . . .WED 1:00 PM TO 3:20 PM

Radar Micro-Doppler

Joint Session with Conferences 9461A and 9461B

Session Chair: **David Tahmoush,** U.S. Army Research Lab. (USA)

Micro-Doppler characteristics of elderly gait patterns with walking aids, Moeness G. Amin, Yimin D. Zhang, Fauzia Ahmad, Villanova Univ. (USA) . . . . [9461-46]

Fall detection and classification using high-resolution time-frequency distributions, Moeness G. Amin, Villanova Univ. (USA); Boualem Boashash, Qatar Univ. (Qatar); Yimin D. Zhang, Villanova Univ. (USA) . . . . [9461-47]

The effectiveness of a staring 3D surveillance system against mitigating wind farm clutter, Mohammed Jahangir, Gordon K. A. Oswald, Max Halbert, Peter Wurmsdobler, Tim Quilter, Aveillant Ltd. (United Kingdom) . . . . . [9461-48]

Human activity classification using time-frequency image analysis of micro-Doppler signatures, Matthew Zenaldin, Ram M. Narayanan, The Pennsylvania State Univ. (USA). . . . . [9461-56]

Study of the micro-Doppler signature of a bicyclist for different directions of approach, Berta Rodriguez-Hervas, The Univ. of Texas at El Paso (USA); Michael Maile, Mercedes-Benz Research & Development North America, Inc. (USA); Benjamin C. Flores, The Univ. of Texas at El Paso (USA) . . . . . . [9461-57]

Extracting and analyzing micro-Doppler from ladar signatures, David Tahmoush, U.S. Army Research Lab. (USA). . . . . [9461-58]

High Range Resolution Micro-Doppler Analysis, Graeme E Smith, Zach Cammenga, Christopher J Baker, The Ohio State University (USA) . . . . [9461-59]

CONFERENCE 9461B

Thursday 23 April 2015 • Part of Proceedings of SPIE Vol. 9461

Active and Passive Signatures VI

Conference Chairs: **G. Charmaine Gilbreath,** U.S. Naval Research Lab. (USA); **Chadwick Todd Hawley,** Senior Expert for Signatures (USA)

Program Committee: **David W. Allen,** National Institute of Standards and Technology (USA); **Kelly W. Bennett,** U.S. Army Research Lab. (USA); **Carlos Omar Font,** U.S. Naval Research Lab. (USA); **Marco O. Lanzagorta,** U.S. Naval Research Lab. (USA); **Ram M. Narayanan,** The Pennsylvania State Univ. (USA); **Frank Pipitone,** U.S. Naval Research Lab. (USA); **Robert Richardson,** U.S. Dept. of Defense Intelligence Information Systems (USA); **Carl Salvaggio,** Rochester Institute of Technology (USA); **Fred Schnarre,** National Geospatial-Intelligence Agency (USA); **David N. Strafford,** Soter Technology (USA)

WEDNESDAY 22 APRIL

SESSION 1. . . . . .WED 1:00 PM TO 3:20 PM

Radar Micro-Doppler

Joint Session with Conferences 9461A and 9461B

Session Chair: **David Tahmoush,** U.S. Army Research Lab. (USA)

Micro-Doppler characteristics of elderly gait patterns with walking aids, Moeness G. Amin, Yimin D. Zhang, Fauzia Ahmad, Villanova Univ. (USA) . . . . [9461-46]

Fall detection and classification using high-resolution time-frequency distributions, Moeness G. Amin, Villanova Univ. (USA); Boualem Boashash, Qatar Univ. (Qatar); Yimin D. Zhang, Villanova Univ. (USA) . . . . [9461-47]

The effectiveness of a staring 3D surveillance system against mitigating wind farm clutter, Mohammed Jahangir, Gordon K. A. Oswald, Max Halbert, Peter Wurmsdobler, Tim Quilter, Aveillant Ltd. (United Kingdom) . . . . . [9461-48]

Human activity classification using time-frequency image analysis of micro-Doppler signatures, Matthew Zenaldin, Ram M. Narayanan, The Pennsylvania State Univ. (USA). . . . . [9461-56]

Study of the micro-Doppler signature of a bicyclist for different directions of approach, Berta Rodriguez-Hervas, The Univ. of Texas at El Paso (USA); Michael Maile, Mercedes-Benz Research & Development North America, Inc. (USA); Benjamin C. Flores, The Univ. of Texas at El Paso (USA) . . . . . . [9461-57]

Extracting and analyzing micro-Doppler from ladar signatures, David Tahmoush, U.S. Army Research Lab. (USA). . . . . [9461-58]

High Range Resolution Micro-Doppler Analysis, Graeme E Smith, Zach Cammenga, Christopher J Baker, The Ohio State University (USA). . . . [9461-59]

THURSDAY 23 APRIL

SESSION 1. . . . . THU 8:30 AM TO 12:00 PM

Active and Passive Signatures I

Application of a laser Doppler vibrometer for air-water to subsurface signature detection, James Roeder, Phillip Land, Dennis J. Robinson, Arun K. Majumdar, Naval Air Warfare Ctr. Weapons Div. (USA) . . . . [9461-60]

Hyperspectral chemical agent standoff detection using sparse representation, Asif Mehmood, Booz Allen Hamilton Inc. (USA) . . . . . [9461-61]

Signature simulation of mixed materials, Tyler Carson, Rochester Institute of Technology (USA) . . . . [9461-62]

Enabling forest structure research with a cost-effective terrestrial LiDAR platform, Jason W. Faulring, Jan A. N. van Aardt, David Kelbe, Paul Romanczyk, Rochester Institute of Technology (USA); Francesco Peri, Crystal Schaff, Univ. of Massachusetts Boston (USA) . . . . [9461-63]

Electro-optical detection probability of optical devices determined by bidirectional laser retro-reflection cross section, Martin Laurenzis, Frank Christnacher, Alexis Matwyschuk, Emmanuel Bacher, Stephane Schertzer, Sebastien Hengy, Institut Franco-Allemand de Recherches de Saint-Louis (France) . . . . [9461-64]

Spectral reflectance variability of skin and attributing factors, Catherine C. Cooksey, Benjamin K. Tsai, David W. Allen, National Institute of Standards and Technology (USA) . . . . [9461-65]

Rugged target standards for HSI remote sensing, Mark Morey, John D. DiBenedetto, Mary O'Neill, National Security Technologies, LLC (USA) . . . . [9461-66]

Enhancing radar cross-section images of artificial targets using radar polarimetry, Thomas Dallmann, Dirk Heberling, RWTH Aachen Univ. (Germany) . . . . [9461-67]

Anomalous reflection of THz pulse containing a few cycles from absorbing layer: influence of absolute phase of the pulse on the medium response, Vyacheslav A. Trofimov, Mikhail V. Fedotova, Elena S. Komarova, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9461-68]

Lunch/Exhibition Break . . . . Thu 12:00 pm to 1:30 pm

SESSION 3 . . . . .THU 1:30 PM TO 2:50 PM

Active and Passive Signatures II

Applying composite signatures to rapidly detect and characterize, Chadwick T. Hawley, U.S. Dept. of Defense (USA) and Help Me Now, LLC (USA) . . . . [9461-69]

Real-time full-motion color FLASH LIDAR for target detection and identification, Roy D. Nelson, Jeremy Craner, Kurt von Niederhausern, Rex M. Craig, Eric Coppock, Ball Aerospace & Technologies Corp. (USA) . . . . [9461-70]

HySpecIQ: realizing the potential of hyperspectral remote sensing informatics in the age of data analytics, Joseph D. Fargnoli, HySpecIQ (USA) . . . . [9461-72]

QUILT: combining stereoscopy with lidar for precision 3D object characterization, G. Charmaine Gilbreath, Carlos Omar Font, David Bonanno, Blerta Bajramaj, Kristen Nock, U.S. Naval Research Lab. (USA) . . . . . . [9461-73

CONFERENCE 9462

Thursday 23 April 2015 • Proceedings of SPIE Vol. 9462

Passive and Active Millimeter-Wave Imaging XVIII

Conference Chairs: **David A. Wikner,** U.S. Army Research Lab. (USA); **Arttu R. Luukanen,** Asqella Corp. (Finland)

Program Committee: **Roger Appleby,** Queen's Univ. Belfast (United Kingdom); **Erich N. Grossman,** National Institute of Standards and Technology (USA); **Christopher A. Martin,** Trex Enterprises Corp. (USA); **Duncan A. Robertson,** Univ. of St. Andrews (United Kingdom); **Bruce Wallace,** Defense Advanced Research Projects Agency (USA)

Thursday 23 April

SESSION 1. . . . . THU 8:00 AM TO 10:00 AM

Systems I

A single pixel millimeter-wave imaging system based on metamaterials, Jiajun Bai, Yunqi Fu, Qiang Chen, Liang Chen, National Univ. of Defense Technology (China) . . . . [9462-1]

Optical and imaging performance testing for an improved real time passive millimetre-wave imager to be used in degraded visual environments, Colin D. Cameron, Rupert N. Anderton, Gordon N. Sinclair, James G. Burnett, Philip J. Kent, QinetiQ Ltd. (United Kingdom). . . . . [9462-2]

Design and operation of ACTPol: a millimeter wavelength, polarization sensitive receiver for the Atacama Cosmology Telescope, Benjamin L. Schmitt, Univ. of Pennsylvania (USA); ACTPol Collaboration, Princeton Univ. (USA) . . . . [9462-3]

Concealed object stand-off real-time imaging for security: CONSORTIS, Roger Appleby, InnovaSec Ltd. (United Kingdom); Stuart Ferguson, Queen's Univ. Belfast (United Kingdom); Henrik Petersson, Swedish Defence Research Agency (Sweden). . . . . [9462-4]

A real time stand-off submillimetre-wave quasi-optical imaging system with large field of view, Erio Gandini, Nuria Llombart, Technische Univ. Delft (Netherlands) . . . . [9462-5]

Noise analysis for near-field 3D FM-CW radar imaging systems, David M. Sheen, Pacific Northwest National Lab. (USA) . . . . [9462-6]

SESSION 2 . . . . THU 10:30 AM TO 11:50 AM

Systems II

Millimeter-wave imaging at up to 40 frames per second using an optoelectronic photo-injected Fresnel zone plate lens antenna at (sub-) mmw frequencies, Thomas F. Gallacher, Aalto Univ. School of Science and Technology (Finland); David G. Macfarlane, Univ. of St. Andrews (United Kingdom); Rune Søndenå, Institute for Energy Technology (Norway); Duncan A. Robertson, Graham M. Smith, Univ. of St. Andrews (United Kingdom) . . [9462-7]

Characteristics and performance of a commercial multiband passive submillimetre-wave video camera, Arttu R. Luukanen, Asqella Oy (Finland); Juha Ala-Laurinaho, Aalto Univ. School of Electrical Engineering (Finland); Alex Kokka, Mikko M. Leivo, Asqella Oy (Finland); Aleksi A. Tamminen, Aalto Univ. School of Electrical Engineering (Finland); Antti V. Räisänen, Aalto Univ. School of Science and Technology (Finland) . . . . [9462-8]

Video rate passive millimeter-wave imager utilizing optical upconversion with improved size, weight, and power, Richard D. Martin, Christopher A. Schuetz, Thomas E. Dillon, Daniel G. Mackrides, Phase Sensitive Innovations, Inc. (USA); Dennis W. Prather, Shouyuan Shi, Univ. of Delaware (USA); Peng Yao, Phase Sensitive Innovations, Inc. (USA); Kevin Shreve, Univ. of Delaware (USA) . . . . [9462-9]

Optical-network-connected multi-channel 96-GHz-band distributed radar system, Atsushi Kanno, Toshiaki Kuri, Tetsuya Kawanishi, National Institute of Information and Communications Technology (Japan). . . . . [9462-10]

Lunch Break . . . . Thu 11:50 am to 1:20 pm

SESSION 3 . . . . THU 1:20 PM TO 2:00 PM

Systems III

Some opinion about matrix terahertz imaging system based on Josephson junctions, Alexander Denisov, Harbin Institute of Technology (China) . . . . [9462-11]

Multiplexable sub-mm detector arrays for radiometric imaging, Juha Hassel, Andrey V. Timofeev, Visa Vesterinen, Hannu Sipola, Panu Helistö, Leif Grönberg, VTT Technical Research Ctr. of Finland (Finland); Arttu R. Luukanen, Asqella Oy (Finland). . . . . [9462-12]

SESSION 4 . . . . THU 2:00 PM TO 4:30 PM

Phenomenology

Toward the development of an image quality tool for the testing of active millimeter-wave imaging systems, Jeffrey Barber, James C. Weatherall, Joseph Greca, Battelle Memorial Institute (USA); Barry T. Smith, U.S. Dept. of Homeland Security (USA) . . . . [9462-13]

Simulations and image validation for 350 GHz passive imaging systems, Daniel T. Becker, National Institute of Standards and Technology (USA); Peter A. R. Ade, Cardiff Univ. (United Kingdom); James A. Beall, National Institute of Standards and Technology (USA); Hsiao-Mei Cho, Stanford Univ. (USA); Simon R. Dicker, Univ. of Pennsylvania (USA); William D. Duncan, National Institute of Standards and Technology (USA); Mark Halpern, The Univ. of British Columbia (Canada); Gene C. Hilton, National Institute of Standards and Technology (USA); Kent D. Irwin, Stanford Univ. (USA); Nicholas G. Paulter Jr., Robert E. Schwall, Carl D. Reintsema, National Institute of Standards and Technology (USA); Carole E. Tucker, Cardiff Univ. (United Kingdom). . . . . [9462-14]

Spectral signatures for identifying explosives with wide-band millimeter-wave illumination, James C. Weatherall, Jeffrey Barber, Battelle Memorial Institute (USA); Barry T. Smith, U.S. Dept. of Homeland Security (USA) [9462-15]

Summary and analysis of 216 GHz polarimetric measurements of in-situ rain, Abigail S. Hedden, David A. Wikner, Russell Bradley, U.S. Army Research Lab. (USA) . . . . [9462-16]

Electromagnetic scattering from metallic and dielectric surfaces at millimeter-wave and terahertz frequencies, David A. DiGiovanni, Andrew J. Gatesman, Robert H. Giles, Univ. of Massachusetts Lowell (USA); Williams E. Nixon, National Ground Intelligence Ctr. (USA). [9462-17]

Beyond the Kirchoff approximation: quantitative studies of submillimeter rough surface scattering, Erich N. Grossman, Richard A. Chamberlin, Josh Gordon, Natalie Mujica-Schwahn, National Institute of Standards and Technology (USA) . . . . [9462-18]

CONFERENCE 9462

SESSION 5 . . . . THU 4:30 PM TO 5:30 PM

Image Processing

Automatic detection of hidden threats in the TeraSCREEN passive millimeter-wave imaging subsystem, Satish Madhogaria, Marek Schikora, Fraunhofer FKIE (Germany) . . . . [9462-19]

Feasibility of radon imaging reconstruction in the MMW region using very inexpensive plasma GDD lamps with new video rate 16x16 FPA camera, Assaf Levanon III, Ben-Gurion Univ. of the Negev (Israel); Michael Konstantinovsky II, Ben-Gurion Univ. of the Negev (Israel) and Intel Corp. (USA); Yitzhak Yitzhaky, Adrian Stern, Natan S. Kopeika, Ben-Gurion Univ. of the Negev (Israel); Amir Abramovich, Ariel Univ. (Israel) . . . . [9462-20]

Real-time image processing for passive mmW imagery, Stephen T. Kozacik, Univ. of Delaware (USA) and EM Photonics, Inc. (USA); James Bonnett, Aaron L. Paolini, EM Photonics, Inc. (USA); Thomas E. Dillon, Richard D. Martin, Christopher A. Schuetz, Phase Sensitive Innovations, Inc. (USA); Dennis W. Prather, Univ. of Delaware (USA) . . . . [9462-21]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Mathematical principles of settings for extremely-high resolution instead of method regularization, Evgeni N. Terentiev, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9462-22]

System analysis and image processing for millimeter-wave holographic imaging based on non-local means, Zheng Li, Tsinghua Univ. (China); Zongjun Shen, Nuctech Co. Ltd. (China); Ziran Zhao, Lingbo Qiao, Tsinghua Univ. (China) . . . . [9462-23]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9463

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9463

Motion Imagery: Standards, Quality, and Interoperability

Conference Chair: **Donnie Self,** National Geospatial-Intelligence Agency (USA)

Program Committee: **Jeffrey Malapit,** AMPS Strategies (USA); **Gary Nadler,** Consultant, Commercial Broadcast Industry (USA); **Norman S. Stein,** InTec, LLC (USA); **Bernie H. Street,** WiSC Enterprises (USA)

Monday 20 April

WELCOME AND OPENING REMARKS . . . . 8:30 AM TO 8:50 AM

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

SESSION 1. . . . . MON 8:50 AM TO 10:30 AM

FMV Foundations

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

Motion Imagery Standards Board (MISB) overview *(Invited Paper)*, Bryan E. Blank, National Geospatial-Intelligence Agency (USA) . . . . [9463-1]

Standards and interoperability 101: standards across the DoD enterprise *(Invited Paper)*, Mark Hary, 2d3 Sensing (USA). . . . . [9463-2]

Compression fundamentals: MPEG2, H.264, and HEVC H.265, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-3]

FMV end-to-end interoperability, Nancy B. Berkowitz, National Geospatial-Intelligence Agency (USA) . . . . [9463-4]

SESSION 2 . . . . MON 11:00 AM TO 12:00 PM

FMV Quality/Interoperability Assessment

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

FMV interoperability assessments and lessons learned, Leilani E. Morton, National Geospatial-Intelligence Agency (USA) . . . . [9463-5]

Video test equipment justification process, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-6]

Automated content and quality assessment of full-motion-video for the generation of meta data, Joshua D. Harguess, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9463-7]

Lunch Break . . . . .Mon 12:00 pm to 1:30 pm

SESSION 3 . . . . MON 1:30 PM TO 2:10 PM

FMV Interface Challenges

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

Interfaces, part one: implementation challenges of uncompressed video: 3G-SDI and HDMI with HDCP, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-8]

Interfaces, part two: implementation challenges of compressed video: transports streams over RF and IP, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-9]

SESSION 4 . . . . MON 2:10 PM TO 3:10 PM

FMV Big Data

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

Big data happiness *(Invited Paper)*, Andrew Eick, Mission Focus (USA); Suzanne Yoakum-Stover, Institute for Modern Intelligence (USA) . . . . . [9463-11]

Collaborative real-time motion video analysis by human observer and image exploitation algorithms, Jutta E. Hild, Wolfgang Krüger, Stefan Bruestle, Patrick Trantelle, Gabriel Unmüssig, Norbert Heinze, Elisabeth Peinsipp-Byma, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany) . . . . [9463-12]

File-based video QC and automation in enterprise and cloud implementations, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-13]

SESSION 5 . . . . MON 3:40 PM TO 4:20 PM

FMV Technical Considerations I

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

CODEC optimization and referenced objective evaluation, Karl J. Kuhn, Tektronix, Inc. (USA) . . . . [9463-14]

New long-zoom lens for 4K super 35mm digital cameras, Laurence J. Thorpe, Ryuhei Kamata, Canon U.S.A., Inc. (USA). . . . . [9463-15]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of
Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 6 . . . . .TUE 8:00 AM TO 9:40 AM

FMV Technical Considerations II

Session Chair: **Donnie B. Self,**
National Geospatial-Intelligence Agency (USA)

A very low-cost system for capturing 3D motion scans with color and texture data, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9463-16]

Projection of controlled repeatable real-time moving targets to test and evaluate motion imagery quality, Stephen D. Scopatz, Electro Optical Industries, Inc. (USA). . . . . [9463-17]

4K, ultra HD, and 8K realities, Karl J. Kuhn, Tektronix, Inc. (USA). . . . [9463-18]

Gamut and camera shading, Karl J. Kuhn, Tektronix, Inc. (USA). . . . . [9463-19]

FMV initiatives, Michael Guthrie, Harmonic, Inc. (USA). . . . . [9463-20]

DEFENSE + SECURITY

CONFERENCE 9464

Monday–Wednesday 20–22 April 2015 • Proceedings of SPIE Vol. 9464

Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR VI

Conference Chairs: **Tien Pham,** U.S. Army Research Lab. (USA); **Michael A. Kolodny,** U.S. Army Research Lab. (USA)

Program Committee: **Kevin L. Priddy,** Air Force Research Lab. (USA); **Flavio Bergamaschi,** IBM United Kingdom Ltd. (United Kingdom); **Robert Heathcock,** U.S. Defense Intelligence Agency (USA); **Olga Mendoza-Schrock,** Air Force Research Lab. (USA); **Gavin Pearson,** Defence Science and Technology Lab. (United Kingdom); **King K. Siu,** U.S. Army Armament Research, Development and Engineering Ctr. (USA); **Raja Suresh,** General Dynamics Advanced Information Systems (USA); **Robert Williams,** Air Force Research Lab. (USA)

Monday 20 April

CHAIRMAN WELCOME . . . . 8:30 AM TO 8:40 AM

SESSION 1. . . . . MON 8:40 AM TO 10:20 AM

Situational Understanding and Anomaly Determination

Session Chairs: **Michael A. Kolodny,** U.S. Army Research Lab. (USA); **Kevin L. Priddy,** Air Force Research Lab. (USA)

Tasking the Tweeters: obtaining actionable information from human sensors, Alun D. Preece, Cardiff Univ. (United Kingdom); Dave Braines, IBM United Kingdom Ltd. (United Kingdom); William Webberley, Cardiff Univ. (United Kingdom) . . . . [9464-1]

Exploring discriminative features for anomaly detection in public spaces, Archan Misra, Singapore Management Univ. (Singapore) . . . . [9464-2]

Detection of anomalous track patterns for long term surveillance, Shuowen Hu, U.S. Army Research Lab. (USA) . . . . [9464-3]

Experiences with an anomaly determination services, Prasanna Giridhar, Tarek Abdelzaher, Univ of Illinois at Urbana-Champaign (USA) . . . . [9464-4]

The use of visual programming tools and techniques for rapid in field situational application development in a coalition environment, David Conway-Jones, IBM United Kingdom Ltd. (United Kingdom) . . . . [9464-5]

SESSION 2 . . . . MON 10:50 AM TO 12:00 PM

Coalition Operations I

Session Chairs: **Tien Pham,** U.S. Army Research Lab. (USA); **Gavin Pearson,** Defence Science and Technology Lab. (United Kingdom)

Unified vision: NATO trials for ISR interoperability technologies *(Invited Paper)*, David L. Payton, U.S. Air Force (USA) . . . . [9464-6]

Standards-based MASINT ISR workflow overview, Eric Chen, Air Force Research Lab. (USA) . . . . [9464-7]

Networks sensing and adaptive processing: vision and challenges, Gavin Pearson, Defence Science and Technology Lab. (United Kingdom) . . . . [9464-8]

Lunch Break . . . . .Mon 12:00 pm to 1:10 pm

SESSION 3 . . . . .MON 1:10 PM TO 1:50 PM

Coalition Operations II

Session Chairs: **Gavin Pearson,** Defence Science and Technology Lab. (United Kingdom); **Tien Pham,** U.S. Army Research Lab. (USA)

Policy controlled access to analytics at the network edge, Geeth de Mel, Jorge J. Ortiz, Seraphin Calo, IBM Thomas J. Watson Research Ctr. (USA); Paul Sullivan, Intelpoint, Inc. (USA) . . . . [9464-9]

Computing on encrypted data and its applicability to a coalition operations environment, Flavio Bergamaschi, Graham Bent, IBM United Kingdom Ltd. (United Kingdom). . . . . [9464-10]

SESSION 4 . . . . MON 1:50 PM TO 3:10 PM

Interoperability and Networking: Architectures and Frameworks

Session Chairs: **Kevin L. Priddy,** Air Force Research Lab. (USA); **Michael A. Kolodny,** U.S. Army Research Lab. (USA)

The convergence of open systems and interoperable systems, Gavin Pearson, Defence Science and Technology Lab. (United Kingdom); John B. Ibbotson, IBM United Kingdom Ltd. (United Kingdom) . . . . [9464-11]

PED fusion via enterprise ontology, James R Schoening, U.S. Army Intelligence and Information Warfare Directorate (I2WD) (USA); Danielle Duff, U.S. Army CERDEC Intelligence and Information Warfare Directorate (USA); Tien Pham, U.S. Army Research Lab. (USA); Justin M. Del Vecchio, Ronald Rudnicki, CUBRC (USA) . . . . [9464-12]

The Sandia architecture for heterogeneous unmanned system control (SAHUC), Joshua A. Love, Stephen Buerger, Jason Neely, Wendy Amai, Charles Q. Little, Sandia National Labs. (USA) . . . . [9464-13]

Dual node decision wheels: an architecture for interconnected information fusion and decision making, Amy L. Sliva, Joe Gorman, Charles River Analytics, Inc. (USA); Christopher L. Bowman, Data Fusion Corp. (USA); Martin Voshell, Charles River Analytics, Inc. (USA) . . . . [9464-14]

SESSION 5 . . . . MON 3:40 PM TO 4:40 PM

Network Sensing and Processing for ISR Applications I

Session Chairs: **Flavio Bergamaschi,** IBM United Kingdom Ltd. (United Kingdom); **Robert Williams,** Air Force Research Lab. (USA)

Acoustical sensor network for hostile fire indicator for ground bases and helicopter-mounted applications, Pierre Naz, Sebastien Hengy, Martin Laurenzis, Institut Franco-Allemand de Recherches de Saint-Louis (France) . . . . [9464-15]

The effect of decentralization and communication networks on a set of ISR-gathering assets, Héctor J. Ortiz-Peña, CUBRC (USA); Michael J. Hirsch, ISEA TEK (USA) and Stetson Univ. (USA); Mark H. Karwan, Univ. at Buffalo (USA); Moises Sudit, CUBRC (USA) and Univ. at Buffalo (USA). . . . . . . [9464-16]

EO vehicle recognition through manifold learning under diverse lighting, Olga Mendoza-Schrock, Air Force Research Lab. (USA); Mateen M. Rizki, Wright State Univ. (USA) . . . . [9464-17]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 6 . . . . .TUE 9:00 AM TO 12:15 PM

Situation Awareness

Joint Session with Conferences 9458 and 9464

Session Chairs: **Igor V. Ternovskiy,** Air Force Research Lab. (USA); **Tien Pham,** U.S. Army Research Lab. (USA)

Situational consciousness for autonomous cyberspace operations *(Keynote Presentation)*, Steven K. Rogers, Air Force Research Lab. (USA). . . . . . . [9458-4]

Situational awareness: a holistic perspective your mother was afraid to tell you, Michael A Kolodny, US Army Research Lab (USA). . . . . [9464-18]

Qualia centric hypothetical thinking: applications to vehicle tracking with the fusion of EO and SAR input data sources *(Invited Paper)*, Jonathan L. White, Harding Univ. (USA); Anthony Helmstetter, Arizona State Univ. (USA); Jared L. Culbertson, Igor V. Ternovskiy, Air Force Research Lab. (USA) . [9458-5]

Automatic video-based classification of small group behavior to support situational understanding, Robert Williams, Air Force Research Lab. (USA); Julie A. Skipper, Skipper Consulting (USA). . . . . [9464-19]

Addressing cyber information overload with cognitive modeling constructs, Sandra L. Vaughan, Air Force Institute of Technology (USA) and U.S. Defense Intelligence Agency (USA); Robert F. Mills, Michael R. Grimaila, Gilbert L. Peterson, Air Force Institute of Technology (USA); Steven K. Rogers, Air Force Research Lab. (USA) . . . . [9458-6]

Why open system approaches matter, Kevin Priddy, Air Force Research Lab. (USA) . . . . [9464-20]

Lunch/Exhibition Break . . . . Tue 12:15 pm to 1:40 pm

SESSION 7 . . . . .TUE 1:40 PM TO 3:20 PM

Network Sensing and Processing for ISR Applications II

Session Chairs: **Olga Mendoza-Schrock,** Air Force Research Lab. (USA); **Michael A. Kolodny,** U.S. Army Research Lab. (USA)

Ground target tracking and classification in a unattended wireless sensor network, Benjamin Pannetier, Jean Dezert, Julien Moras, ONERA (France); Loic Canevet, Didier Cosson, Delegation Generale Pour L'Armament (France) . . . . [9464-21]

Feature extraction and classification using neurosynaptic processing at the edge of the network, Flavio Bergamaschi, Graham Bent, IBM United Kingdom Ltd. (United Kingdom) . . . . [9464-22]

UAV as a generic information provider in an ISR System of Systems, Jurgo Preden, Jaanus Kaugerand, Erki Suurjaak, Raido Pahtma, Sergei Astapov, Leo Motus, Tallinn Univ. of Technology (Estonia) . . . . [9464-23]

A micro services architecture for use by microcontroller driven devices to provide interoperability with the open lean services architecture, Nicholas Peach, 2iC Ltd. (United Kingdom). . . . . [9464-24]

Visibility based multi-agent surveillance strategies in decentralized network, Rui Zou, Sourabh Bhattacharya, Iowa State Univ. (USA) . . . . [9464-25]

SESSION 8 . . . . .TUE 3:50 PM TO 5:10 PM

Sensor, Data and Information Processing and Fusion Algorithms

Session Chairs: **Kevin L. Priddy,** Air Force Research Lab. (USA); **Gavin Pearson,** Defence Science and Technology Lab. (United Kingdom)

Bayesian hidden Markov models for UAV-enabled target localization on road networks with soft-hard data, Nisar R. Ahmed, Univ. of Colorado at Boulder (USA); David Casbeer, Yongcan Cao, Derek B. Kingston, Air Force Research Lab. (USA) . . . . [9464-26]

Corrected pose data for the Wright Patterson Air Force Base (WPAFB) 2009 wide area motion imagery (WAMI) data set, Curtis Cohenour, Ohio Univ. (USA); Rebecca L. Price, U.S. Air Force (USA); Todd V. Rovito, Air Force Research Lab. (USA); Frank van Graas, Ohio Univ. (USA) . . . . [9464-27]

Classification of vibrometry data, Karmon M. Vongsy, Air Force Research Lab. (USA); Ashley N. Smith, Wright State Univ. (USA) . . . . [9464-28]

Predicting exploitation success on compressed imagery through common image quality metrics: an initial look, Christopher McGuinness, Univ. of Dayton Research Institute (USA). . . . . [9464-29]

Wednesday 22 April

SESSION 9 . . . . .WED 1:20 PM TO 4:30 PM

Novel Sensing and Signal Processing

Session Chairs: **Olga Mendoza-Schrock,** Air Force Research Lab. (USA); **Flavio Bergamaschi,** IBM United Kingdom Ltd. (United Kingdom)

Real-time algorithms for data reduction and smart sensing with high frame rate CMOS image sensor, Blake C. Jacquot, Nathan G. Johnson-Williams, The Aerospace Corp. (USA) . . . . [9464-30]

Beyond H.264: implications of next generation video compression on surveillance imagery, Christopher McGuinness, Univ. of Dayton Research Institute (USA) . . . . [9464-31]

Binocular link for smartphone (BLINKS) demonstration, Paul Yun, King K. Siu, Paul D. Willson, U.S. Army Armament Research, Development and Engineering Ctr. (USA); Fred J. Fitzsimmons, Contractor (USA). . . . . . . [9464-32]

Phased array beamformer performance in variable environments, David R. Bergman, Exact Solution Scientific Consulting LLC (USA). . . . . [9464-33]

Classification of uncooperative vehicles with sparse laser Doppler vibrometry measurements, Jie Wei, Chi-Him Liu, Zhigang Zhu, The City College of New York (USA); Olga Mendoza-Schrock, Karmon M. Vongsy, Air Force Research Lab. (USA). . . . . [9464-34]

Sources of uncertainty in feature-based image registration algorithms, Paul Sundlie, Joseph Fernando, Univ. of Dayton Research Institute (USA); Clark N. Taylor, Air Force Research Lab. (USA) . . . . [9464-35]

Ultra-wideband 3D position referenced environment for enhanced detection, marking, neutralization and change detection, David J. Bruemmer, 5D Robotics Inc. (USA); Robert L. Wade, U.S. Army Armament Research, Development and Engineering Ctr. (USA); Vince Matriciano, U.S. Army Program Executive Office Ammunition (USA); Jon Whetten, R. Scott Hartley, 5D Robotics Inc. (USA) . . . . [9464-36]

YUV chrominance sub-sampling comparison using H.264, Andrew Thompson, Eric Balster, Univ. of Dayton (USA) . . . . [9464-37]

CONFERENCE 9465A

Tuesday–Wednesday 21–22 April 2015 • Part of Proceedings of SPIE Vol. 9465

Laser Radar Technology and Applications XX

Conference Chairs: **Monte D. Turner,** Air Force Research Lab. (USA); **Gary W. Kamerman,** FastMetrix, Inc. (USA)

Program Committee: **Philip Gatt,** Lockheed Martin Coherent Technologies (USA); **Dominique Hamoir,** ONERA (France); **Richard M. Heinrichs,** Defense Advanced Research Projects Agency (USA); **Vasyl Molebny,** National Taras Shevchenko Univ. of Kyiv (Ukraine); **Russell Philbrick,** North Carolina State Univ. (USA); **Upendra N. Singh,** NASA Langley Research Ctr. (USA); **Ove K. Steinvall,** Swedish Defence Research Agency (Sweden); **Douglas G. Youmans,** SPARTA Inc./Parsons Corp. (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 8:20 AM TO 10:00 AM

LIDAR Design/Demonstrations

Session Chair: **Monte D. Turner,** Air Force Research Lab. (USA)

Imaging flash lidar for safe landing on solar system bodies and spacecraft rendezvous and docking, Farzin Amzajerdian, Vincent E. Roback, NASA Langley Research Ctr. (USA); Alexander E. Bulyshev, Analytical Mechanics Associates, Inc. (USA); Paul F. Brewster, Glenn D. Hines, NASA Langley Research Ctr. (USA); Diego F. Pierrottet, Coherent Applications, Inc. (USA); Larry B. Petway, NASA Langley Research Ctr. (USA). . . . . [9465-1]

Improved resolution in time-of-flight measurement in a multi-pulse scanning-ladar system, Yury Y. Markushin, Renu Tripathi, Gour S. Pati, Delaware State Univ. (USA). . . . . [9465-2]

Laser safety in design of near-infrared scanning lidars, Xiang Zhu, Dave Elgin, Neptec Design Group Ltd. (Canada) . . . . [9465-3]

Novel, ultra-compact, high-performance, eye-safe laser rangefinder for demanding applications, Mark Silver, Stephen T. Lee, Andrew G. Borthwick, Graham Morton, Craig McNeill, David McSporran, Ian McRae, Gordon McKinlay, William Alexander, David Jackson, Craig Smith, Colin Scouller, Thales Optronics Ltd. (United Kingdom). . . . . [9465-4]

OEM fiber laser rangefinder for long-distance measurement, Alexandre Corman, Frédéric Chiquet, Thomas Avisse, SensUp (France); Marc Le Flohic, Keopsys SA (France); Nicolas Picard, SensUp (France) . . . . [9465-5]

SESSION 2 . . . . .TUE 10:30 AM TO 11:50 AM

Emerging LIDAR Applications I

Session Chair: **Gary Kamerman,** FastMetrix, Inc. (USA)

Active and passive EO sensing for the detection of humans and handheld objects, Ove Steinvall, Håkan Larsson, Magnus Pettersson, Swedish Defence Research Agency (Sweden) . . . . [9465-6]

Anomaly detection in clutter using spectrally enhanced ladar, Puneet S. Chhabra, Andrew M. Wallace, Heriot-Watt Univ. (United Kingdom); James R. Hopgood, The Univ. of Edinburgh (United Kingdom) . . . . [9465-7]

Study of a dual mode SWIR active imaging system for direct imaging and non line of sight vision, Martin Laurenzis, Frank Christnacher, Institut Franco-Allemand de Recherches de Saint-Louis (France); Andreas Velten, Univ. of Wisconsin-Madison (USA) and Morgridge Institute for Research (USA). . [9465-8]

High efficiency chirped Bragg gratings for stretching and compression of ultra short laser pulses at 800 nm, Vadim Smirnov, Leonid B. Glebov, Alexei L. Glebov, Oleksiy Mokhun, Larissa Glebova, Eugeniu Rotari, Ion Cohanoschi, Oleg Smolsky, OptiGrate Corp. (USA) . . . . [9465-9]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . TUE 1:20 PM TO 2:00 PM

Emerging LIDAR Applications II

Session Chair: **Gary Kamerman,** FastMetrix, Inc. (USA)

Atmospheric aerosol and molecular backscatter imaging effects on direct detection ladar, Douglas G. Youmans, Parsons Corp. (USA) . . . . [9465-10]

All-fiber, compact, coherent wind lidar development for environmental monitoring applications, Narasimha S. Prasad, NASA Langley Research Ctr. (USA); Steven Vetorino, Allen J. Tracy, Rich Higgins, Russel Sibell, Sibelloptics, LLC (USA) . . . . [9465-11]

SESSION 4 . . . . TUE 2:00 PM TO 4:10 PM

Advanced and Realtime LIDAR Data Processing

Session Chair: **Ove Steinvall,**
Swedish Defence Research Agency (Sweden)

Automated feature extraction for 3-dimensional point clouds, Alexander A. Soderlund, Johnathan H. Racz, Amy L. Neuenschwander, Lori A. Magruder, Applied Research Lab. (USA) . . . . [9465-12]

Dynamic voxel modeling resolution based on quality assessments from lidar path tracing, Shea Hagstrom, Joshua B. Broadwater, Johns Hopkins Univ. Applied Physics Lab., LLC (USA). . . . . [9465-13]

Agile-beam laser radar using computational imaging for robotic perception, Michael A. Powers, General Dynamics Robotic Systems (USA); Barry L. Stann, Mark M. Giza, U.S. Army Research Lab. (USA) . . . . [9465-14]

Low-SWaP coincidence processing for Geiger-mode lidar video, Myron Z. Brown, Noel P. Cervino, Zachary D. Kurtz, Steven E. Schultz, Johns Hopkins Univ. (USA) . . . . [9465-15]

Real-time on-board airborne demonstration of high-speed on-board data processing for science instruments (HOPS), Jeffrey Y. Beyon, Tak-Kwong Ng, Mitchell J. Davis, James K. Adams, Stephen C. Bowen, James J. Fay, Mark A. Hutchinson, NASA Langley Research Ctr. (USA) . . . . [9465-16]

Wednesday 22 April

SESSION 5 . . . . .WED 9:00 AM TO 10:00 AM

3D Data Fusion and Visualization

Session Chair: **Douglas G. Youmans,** Parsons Corp. (USA)

Registration of multiple texel images (fused lidar/digital imagery) to form a 3D image, Mehedi Hasan, Scott E. Budge, Utah State Univ. (USA) . . . [9465-17]

Textured digital elevation model formation from low-cost UAV ladar/digital image data, Taylor C. Bybee, Scott E. Budge, Utah State Univ. (USA). [9465-18]

Visualization of 3D images from multiple texel images created from fused lidar/digital imagery, Cody Killpack, Scott E. Budge, Utah State Univ. (USA) . . . . [9465-19]

DEDICATED EXHIBITION TIME AND LUNCH BREAK

10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 5 . . . . .WED 1:00 PM TO 2:20 PM

LIDAR Foliage Penetration Imaging

Session Chair: **Monte D. Turner,** Air Force Research Lab. (USA)

Modeling individual tree crowns in an urban environment using dense discrete return lidar, Madhurima Bandyopadhyay, Jan A. N. van Aardt, Martin van Leeuwen, Rochester Institute of Technology (USA) . . . . [9465-20]

Simulation of lidar propagation through a tree canopy in 3D, Angela M. Kim, Richard C. Olsen, Naval Postgraduate School (USA); Martin Béland, Univ. Laval (Canada) . . . . [9465-21]

Comparison of full-waveform, photon counting and discrete analog lidar data, Scott C. Runyon, Angela M. Kim, Jeremy P. Metcalf, Richard C. Olsen, Naval Postgraduate School (USA). . . . . [9465-22]

Exploitation of multi-wavelength lidar for terrain classification and foliage penetration, Richard C. Olsen, Naval Postgraduate School (USA); Chelsea H. Esterline, Naval Postgraduate School (Chile); Angela M. Kim, Jeremy P. Metcalf, Naval Postgraduate School (USA). . . . . [9465-23]

CONFERENCE 9465B

Thursday 23 April 2015 • Part of Proceedings of SPIE Vol. 9465

Atmospheric Propagation XII

Conference Chairs: **Linda M. Wasiczko Thomas,** U.S. Naval Research Lab. (USA); **Earl J. Spillar,** Air Force Research Lab. (USA)

Program Committee: **Ammar Al-Habash,** Raytheon Space & Airborne Systems (USA); **Gary Baker,** Lockheed Martin Space Systems Co. (USA); **Gary G. Gimmestad,** Georgia Tech Research Institute (USA); **Ken J. Grant,** Defence Science and Technology Organisation (Australia); **Juan C. Juarez,** Johns Hopkins Univ. Applied Physics Lab. (USA); **Christopher I. Moore,** U.S. Naval Research Lab. (USA); **William S. Rabinovich,** U.S. Naval Research Lab. (USA); **Jonathan M. Saint Clair,** The Boeing Co. (USA); **David H. Tofsted,** U.S. Army Research Lab. (USA); **Morio Toyoshima,** National Institute of Information and Communications Technology (Japan); **Cynthia Y. Young,** Univ. of Central Florida (USA)

Thursday 23 April

SESSION 6 . . . . THU 9:00 AM TO 10:20 AM

Atmospheric Turbulence I

Session Chair: **Juan C. Juarez,** Johns Hopkins Univ. Applied Physics Lab., LLC (USA)

An updated look at tilt-removed beam propagation in the atmosphere, Gary Baker, Lockheed Martin Space Systems Co. (USA) . . . . [9465-24]

Wavefront sensing and phase reconstruction with multi-aperture Zernike filter, Mikhail A. Vorontsov, Univ. of Dayton (USA) and Optonicus (USA); Svetlana L. Lachinova, Mathieu Aubailly, Optonicus (USA); Behzad Bordbar, Univ. of Dayton (USA) . . . . [9465-25]

Optical turbulence with anisotropy at different scales and its effect on laser beam propagation along vertical paths, Italo Toselli, Olga Korotkova, Univ. of Miami (USA). . . . . [9465-26]

Scientific data analysis of atmospheric turbulence through distributed computing, Sara B. Belichki, Christopher A. Smith, Joseph T. Coffaro, Michael G. Panich, Ronald L. Phillips, Larry C. Andrews, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9465-27]

SESSION 7 . . . . THU 10:50 AM TO 12:30 PM

Atmospheric Turbulence II

Session Chair: **Gary Baker,** Lockheed Martin Space Systems Co. (USA)

A low cost, low power, S-band radar for atmospheric turbulence studies, Thomas C. Farrell, Air Force Research Lab. (USA) . . . . [9465-28]

Evaluation of atmospheric refractive index gradient variability from time-lapse imaging, Jack E. McCrae, Santasri Basu, Air Force Institute of Technology (USA) and Oak Ridge Institute for Science & Education (USA); Zach B. Pollock, Miami Univ. (USA); Steven T. Fiorino, Air Force Institute of Technology (USA) . . . . [9465-29]

Increasing persistence through scattering environments by using circularly polarized light, John D. van der Laan, College of Optical Sciences, The Univ. of Arizona (USA) and Sandia National Labs. (USA); David A. Scrymgeour, Jeremy B. Wright, Shanalyn A. Kemme, Sandia National Labs. (USA); Eustace L. Dereniak, College of Optical Sciences, The Univ. of Arizona (USA) . . . . [9465-30]

Scintillation effects of double-pass optical beams in atmospheric turbulence, Joseph T. Coffaro, Michael G. Panich, Univ. of Central Florida (USA); Sara B. Belichki, Christopher A. Smith, Ronald L. Phillips, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Larry C. Andrews, Univ. of Central Florida (USA) . . . . [9465-31]

The spectral transparency of the surface layer marine and coastal atmosphere, Gennady A. Kaloshin, V.E. Zuev Institute of Atmospheric Optics (Russian Federation) . . . . [9465-32]

Lunch/Exhibition Break . . . . Thu 12:30 pm to 1:50 pm

SESSION 8 . . . . THU 1:50 PM TO 3:30 PM

Free Space Laser Communication

Session Chair: **Christopher I. Moore,** U.S. Naval Research Lab. (USA)

Low-SWAP lasercomm terminal architecture for high-bandwidth communications under highly scintillated links, Juan C. Juarez, Radha Venkat, Ryan P. DiNello-Fass, David M. Brown, Hala Tomey, Johns Hopkins Univ. Applied Physics Lab., LLC (USA). . . . . [9465-33]

Lasercomm beacon architecture for link acquisition in highly scintillated environments, Radha Venkat, Juan C. Juarez, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . . [9465-34]

Demonstrating capacity-approaching FSO communications, Thomas R. Halford, Michael P. Fitz, Cenk Kose, Jonathan Cromwell, Steven Gordon, TrellisWare Technologies, Inc. (USA) . . . . [9465-35]

The ONR high-bandwith Lasercom project update, Linda M. Thomas, Christopher I. Moore, William S. Rabinovich, U.S. Naval Research Lab. (USA) . . . . [9465-36]

The ONR high-bandwidth lasercom project: analysis of propagation data, William S. Rabinovich, Christopher I. Moore, Linda M. Thomas, U.S. Naval Research Lab. (USA) . . . . [9465-37]

INTERACTIVE POSTER SESSION

THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

The effect of the aero-optic's additional focal length on the airborne platform laser communication optical system, Yuan Hu, Changchun Univ. of Science and Technology (China) and Beijing Institute of Technology (China); Tianyuan Gao, Changchun Univ. of Science and Technology (China); Dewen Cheng, Beijing Institute of Technology (China); Shoufeng Tong, Huilin Jiang, Changchun Univ. of Science and Technology (China) . . . . [9465-38]

CONFERENCE 9466

Tuesday–Wednesday 21–22 April 2015 • Proceedings of SPIE Vol. 9466

Laser Technology for Defense and Security XI

Conference Chairs: **Mark Dubinskii,** U.S. Army Research Lab. (USA); **Stephen G. Post,** Missile Defense Agency (USA)

Program Committee: **Steven R. Bowman,** U.S. Naval Research Lab. (USA); **Iyad Dajani,** Air Force Research Lab. (USA); **Fabio Di Teodoro,** The Aerospace Corp. (USA); **Anthony M. Johnson,** Univ. of Maryland, Baltimore County (USA); **Don D. Seeley,** High Energy Laser Joint Technology Office (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 8:40 AM TO 10:00 AM

Mid-IR and UV-Vis Lasers

Session Chair: **Anthony M. Johnson,** Univ. of Maryland, Baltimore County (USA)

Ring cavity surface emitting quantum cascade laser with a near Gaussian beam profile, Pedro N. Figueiredo, Robert E. Peale, Andrey V. Muraviev, Univ. of Central Florida (USA). . . . . [9466-1]

Continuous-wave deep ultraviolet sources for resonance Raman explosive sensing, Balakishore Yellampalle, Robert B. Martin, Mikhail Sluch, Robert V. Ice, William B. McCormick, Brian E. Lemoff, West Virginia High Technology Consortium Foundation (USA). . . . . [9466-2]

AlGaInN laser diode technology and systems for defence and security applications, Stephen P. Najda, Piotr Perlin, Tadek Suski, Lucja Marona, Mike Bockowski, Mike Leszczynski, Przemek Wisniewski, Robert Czernecki, TopGaN Ltd. (Poland); Robert Kucharski, Ammono S.A. (Poland); George Tagowski, TopGaN Ltd. (Poland); Scott Watson, Antony Kelly, Univ. of Glasgow (United Kingdom) . . . . [9466-3]

Recent progress in high-power ultrafast thulium-doped fiber lasers and mid-infrared supercontinuum sources, Jiang Liu, Hongxing Shi, Kun Liu, Fangzhou Tan, Pu Wang, Beijing Univ. of Technology (China) . . . . [9466-4]

SESSION 2 . . . . .TUE 10:30 AM TO 11:50 AM

Progress in Diode Lasers/Novel Bulk Solid-state Lasers

Session Chair: **Mark Dubinskii,** U.S. Army Research Lab. (USA)

High temperature operating diode laser pumps for directed energy fiber lasers, Manoj Kanskar, Ling Bao, Zhigang Chen, Mark DeVito, Weimin Dong, Xingguo Guan, David M. Hemenway, Walter Sanders, Jim Zhang, Shiguo Zhang, nLIGHT Corp. (USA) . . . . [9466-5]

Higher efficiency low weight, high-brightness fiber pump modules, David A. Irwin, DILAS Diode Laser, Inc. (USA); Andreas Bayer, Wilhelm Fassbender, Jens Biesenbach, DILAS Diodenlaser GmbH (Germany); Steven G. Patterson, DILAS Diode Laser, Inc. (USA) . . . . [9466-6]

Resonantly pumped, Kerr-lens mode-locked Er:YVO_4 laser, Nikolay E. Ter-Gabrielyan, Viktor Fromzel, Mark Dubinskii, U.S. Army Research Lab. (USA) . . . . [9466-7]

DBR and DFB lasers in Nd and Yb doped photo-thermo-refractive glasses, Aleksandr I. Ryasnyanskiy, OptiGrate Corp. (USA); Nikolai Vorobiev, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Vadim Smirnov, OptiGrate Corp. (USA); Julien Lumeau, Larissa Glebova, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Oleksiy Mokhun, Christine Spiegelberg, OptiGrate Corp. (USA); Michael A. Krainak, NASA Goddard Space Flight Ctr. (USA); Alexei L. Glebov, OptiGrate Corp. (USA); Leonid B. Glebov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) and OptiGrate Corp. (USA). . . . . [9466-8]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . .TUE 1:20 PM TO 3:00 PM

Fiber Lasers: Power Scaling

Session Chair: **Stephen G. Post,** Missile Defense Agency (USA)

High-power operation of Yb-doped fiber laser at 976 nm. Present status and applications *(Invited Paper)*, Eric Cormier, Univ. Bordeaux 1 (France) . . . . [9466-9]

Advances in resonantly-pumped Tm-doped fiber amplifiers, Daniel Creeden, Benjamin R. Johnson, Glen A. Rines, Scott D. Setzler, BAE Systems (USA). . . . . [9466-10]

Higher order mode selection for power scaling in laser resonators using transmitting Bragg gratings, Brian M. Anderson, George B. Venus, Daniel Ott, Ivan B. Divliansky, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Jay W. Dawson, Derrek R. Drachenberg, Michael J. Messerly, Paul H. Pax, John B. Tassano, Lawrence Livermore National Lab. (USA); Leonid B. Glebov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9466-11]

Laser beam characteristics of optical phased arrays, Yakov G. Soskind, DHPC Technologies (USA) . . . . [9466-12]

SESSION 4 . . . . TUE 3:30 PM TO 5:10 PM

New Laser and Nonlinear Materials and Their Properties

Session Chair: **George A. Newburgh,** U.S. Army Research Lab. (USA)

Thermally and mechanically enhanced phosphate glasses for eye-safe lasers, Paula Vullo, Simi A. George, SCHOTT North America, Inc. (USA) . . . . [9466-13]

Magneto-optical properties of fluorinated silicate glasses doped with rare earth ions, Aleksandr I. Ryasnyanskiy, Vadim Smirnov, OptiGrate Corp. (USA); Helene Mingareev, Axel Schülzgen, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Alexei L. Glebov, OptiGrate Corp. (USA); Larissa Glebova, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA); Leonid B. Glebov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) and OptiGrate Corp. (USA) . . [9466-14]

Transition metal doped gallium nitride laser materials, Steven Bowman, U.S. Naval Research Lab. (USA); Christopher G. Brown, Univ. Research Foundation (USA); Jacob H. Leach, Kevin Udwary, Kyma Technologies, Inc. (USA) [9466-15]

Frequency conversion with quasi-phase matched gallium nitride, Steven Bowman, U.S. Naval Research Lab. (USA); Christopher G. Brown, Univ. Research Foundation (USA); Jennifer K. Hite, Jaime A. Freitas Jr., Francis J. Kub, Charles R. Eddy Jr., Jerry R. Meyer, Igor Vurgaftman, U.S. Naval Research Lab. (USA); Jacob H. Leach, Kevin Udwary, Kyma Technologies, Inc. (USA) . . . . [9466-16]

Spectroscopic properties of Er-doped Y2O3 ceramic related to mid-IR laser transition, Tigran Sanamyan, Zackery D. Fleischman, U.S. Army Research Lab. (USA) . . . . [9466-17]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Yb-fiber-MOPA based high energy and average power uplink laser beacon for deep space communication operating under Nested PPM format, Doruk Engin, Ibraheem Darab, John Burton, Frank Kimpel, Shantanu Gupta, Fibertek, Inc. (USA). . . . . [9466-30]

Proposal of a defense application for a chemical oxygen laser, Kiwamu Takehisa, O2 Laser Lab. (Japan). . . . . [9466-31]

Wednesday 22 April

SESSION 5 . . . . WED 8:20 AM TO 10:00 AM

Pulsed Fiber Lasers and SBS Mitigation

Session Chair: **Steven Bowman,** U.S. Naval Research Lab. (USA)

Stimulated Brillouin scattering in optical fibers with end reflections excited by broad-band pump waves with different spectral shapes, Mark S. Bowers, Robert S. Afzal, Lockheed Martin Aculight (USA) . . . . [9466-18]

Mode-locked and Q-switched fiber lasers with graphene oxide based saturable absorber *(Invited Paper)*, Pu Wang, Jiang Liu, Beijing Univ. of Technology (China) . . . . [9466-19]

Narrow-band, all-fiber 100W 20-ps Yb-doped fiber laser source, Robert A. Stegeman, Ye Huang, Eric D. Park, Peter F. Moulton, Q-Peak, Inc. (USA) . . . . [9466-20]

Arbitrary phase modulation for optical spectral control and suppression of stimulated Brillouin scattering, Johan Nilsson, Achar V. Harish, Univ. of Southampton (United Kingdom) . . . . [9466-21]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 6 . . . . WED 1:20 PM TO 3:00 PM

Novel Fiber Lasers

Session Chair: **Don D. Seeley,**
High Energy Laser Joint Technology Office (USA)

Continuous-wave fiber Raman lasers cladding-pumped directly by diodes *(Invited Paper)*, Johan Nilsson, Tianfu Yao, Achar V. Harish, Jayanta K. Sahu, Univ. of Southampton (United Kingdom) . . . . [9466-22]

Diode pumped Tm/Ho composite Fiber 2.1 µm laser, George A. Newburgh, U.S. Army Research Lab. (USA) . . . . [9466-23]

Extra-low Brillouin gain optical fiber derived from Er-doped sapphire ceramic, Mark Dubinskii, Tigran Sanamyan, Robert Pavlacka, U.S. Army Research Lab. (USA); Thomas W. Hawkins, Clemson Univ. (USA); Peter D. Dragic, Univ. of Illinois at Urbana-Champaign (USA); John Ballato, Clemson Univ. (USA) . . . . [9466-24]

Power scaling of resonantly-pumped double-clad fiber laser based on Yb-free Er-doped silicate glass, Jun Zhang, Radha Pattnaik, U.S. Army Research Lab. (USA); Shibin Jiang, AdValue Photonics, Inc. (USA); Mark Dubinskii, U.S. Army Research Lab. (USA) . . . . [9466-25]

SESSION 7 . . . . WED 3:30 PM TO 4:50 PM

Novel Laser-based Practical Devices and Systems

Session Chair: **Nikolay E. Ter-Gabrielyan,**
U.S. Army Research Lab. (USA)

Novel broadly tunable fiber laser system, Steven Bowman, U.S. Naval Research Lab. (USA); Christopher G. Brown, Univ. Research Foundation (USA) . . . . [9466-26]

A passively q-switched compact solid-state laser, Bhabana Pati, Eric D. Park, Q-Peak, Inc. (USA). . . . . [9466-27]

Development of a compact laser target designator, Stephen T. Lee, Andrew G. Borthwick, Graham Morton, Ian McRae, Norman Imlach, George Gardiner, Gordon McKinlay, William Alexander, Mark Silver, Thales UK Ltd. (United Kingdom). . . . . [9466-28]

20.2W CW 2.118µm Ho:$YAlO_3$ laser pumped by 1.915µm Tm-doped fiber laser, Ting Yu, Gang Bai, Zhongguo Yang, Weibiao Chen, Shanghai Institute of Optics and Fine Mechanics (China). . . . . [9466-29]

CONFERENCE 9467

Monday–Friday 20–24 April 2015 • Proceedings of SPIE Vol. 9467

Micro- and Nanotechnology Sensors, Systems, and Applications VII

Conference Chairs: **Thomas George,** ChromoLogic (USA); **Achyut K. Dutta,** Banpil Photonics, Inc. (USA); **M. Saif Islam,** Univ. of California, Davis (USA)

Program Committee: **Roger Appleby,** Queen's Univ. Belfast (United Kingdom); **Debjyoti Banerjee,** Texas A&M Univ. (USA); **Michael P. Buric,** National Energy Technology Lab. (USA); **Richard Conroy,** National Institutes of Health (USA); **Ertugrul Cubukcu,** Univ. of Pennsylvania (USA); **Aykutlu Dana,** Bilkent Univ. (Turkey); **Nibir K. Dhar,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Muhammad M. Hussain,** King Abdullah Univ. of Science and Technology (Saudi Arabia); **Matthew E. L. Jungwirth,** Honeywell Defense and Space Electronic Systems (USA); **Anupama B. Kaul,** National Science Foundation (USA); **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **Susan M. Maley,** U.S. Dept. of Energy (USA); **Michael C. McAlpine,** Princeton Univ. (USA); **Parvaneh Mokarian-Tabari,** Univ. College Coek (Ireland); **William D. Nothwang,** U.S. Army Research Lab. (USA); **Stergios J. Papadakis,** Johns Hopkins Univ. Applied Physics Lab., LLC (USA); **Michael K. Rafailov,** The Reger Group (USA); **Bilge Saruhan-Brings,** Deutsches Zentrum für Luft- und Raumfahrt (Germany); **Antonio Sastre,** National Institutes of Health (USA); **Noriko Satake,** UC Davis Medical Ctr. (USA); **Sivalingam Sivananthan,** Univ. of Illinois at Chicago (USA); **Andre U. Sokolnikov,** Visual Solutions and Applications (USA); **Kyung-Ah Son,** HRL Labs., LLC (USA); **Thomas G. Thundat,** Univ. of Alberta (Canada); **Richard Vaia,** Air Force Research Lab. (USA); **Christopher C. Wilcox,** U.S. Naval Research Lab. (USA); **Joyce Wong,** Schlumberger Ltd. (USA), California Institute of Technology {United States); **Eui-Hyeok Yang,** Stevens Institute of Technology (USA)

Monday 20 April

SESSION 1. . . . . MON 8:00 AM TO 12:30 PM

Flexible, Stretchable, Transient Electronics: What's Next?

Session Chair: **Muhammad M. Hussain,** King Abdullah Univ. of Science and Technology (Saudi Arabia)

Epidermal and bioresorbable electronic systems for clinical medicine *(Invited Paper)*, John A. Rogers, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9467-1]

Edible Electronics: materials and devices for next-generation medical implants *(Invited Paper)*, Christopher J. Bettinger, Carnegie Mellon Univ. (USA) . . . . [9467-2]

A strategy for establishing stable contact between machine/biological tissue *(Invited Paper)*, Sungwon Lee, The Univ. of Tokyo (Japan) . . . . . . [9467-3]

Molecularly stretchable electronics for mechanically robust and wearable semiconductor devices *(Invited Paper)*, Darren J. Lipomi, Univ. of California, San Diego (USA) . . . . [9467-4]

Soft Electronics: current trends and future challenges *(Invited Paper)*, Rebecca K. Kramer, Purdue Univ. (USA) . . . . [9467-5]

Liquid metals as ultra-stretchable, soft, and shape reconfigurable conductors *(Invited Paper)*, Michael D. Dickey, North Carolina State Univ. (USA) . . . . [9467-6]

Transformational electronics are now reconfiguring *(Invited Paper)*, Muhammad M. Hussain, Jhonathan Rojas, Galo Torres Sevilla, Aftab Hussain, Sally Ahmed, Joanna Nassar, Rabab Bahabry, Arwa Kutbee, Bidoor Alsaif, Amani Almuslem, Nasir Alfaraj, Meshal Alawein, King Abdullah Univ. of Science and Technology (Saudi Arabia) . . . . [9467-7]

Low cost, high throughput cut-and-paste manufacture of multifunctional epidermal electronic systems *(Invited Paper)*, Nanshu Lu, The Univ. of Texas at Austin (USA) . . . . [9467-8]

Flexible phosphorene devices and circuits *(Invited Paper)*, Weinan Zhu, Deji Akinwande, The Univ. of Texas at Austin (USA). . . . . [9467-9]

Transfer printing methods for fabricating nanowire devices on diverse substrates *(Invited Paper)*, Xiaolin Zheng, Stanford Univ. (USA) . . . . . . [9467-10]

High performance biointegrated electronic devices *(Invited Paper)*, Dae-Hyeong Kim, Donghee Son, Jaemin Kim, Seoul National Univ. (Korea, Republic of) . . . . [9467-11]

Paper electronics: the next flexible, foldable,and stretchable electronics *(Invited Paper)*, Jr-Hau He, King Abdullah Univ. of Science and Technology (Saudi Arabia); Der-Hsien Lien, Po-Kang Yang, National Taiwan Univ. (Taiwan); Chun-Ho Lin, King Abdullah Univ. of Science and Technology (Saudi Arabia) . . . . [9467-12]

Lunch Break . . . . Mon 12:30 pm to 1:30 pm

SESSION 2 . . . . MON 1:30 PM TO 3:10 PM

Low-Intensity Energy Delivery for Biomodulation I

Joint Session with Conferences 9467 and 9460

Session Chair: **Richard Conroy,** National Institutes of Health (USA)

20 kHz ultrasound assisted treatment of chronic wounds with concurrent optic monitoring *(Invited Paper)*, Peter A. Lewin, Christopher R. Bawiec, Youhan Sunny, Joshua A. Samuels, Drexel Univ. (USA); Michael S. Weingarten, Drexel Univ. College of Medicine (USA); Leonid A. Zubkov, Drexel Univ. (USA); David J. Margolis, Univ. of Pennsylvania (USA); Michael T. Neidrauer, Drexel Univ. (USA) . . . . [9467-13]

Guiding tissue regeneration in vitro and in vivo with ultrasound technologies *(Invited Paper)*, Diane Dalecki, Denise C. Hocking, Univ. of Rochester (USA) . . . . [9467-14]

Ultrasound induced neurostimulation *(Invited Paper)*, Randy L. King, U.S. Food and Drug Administration (USA) . . . . [9467-15]

Targeted delivery of GABA via ultrasound-induced blood-brain barrier disruption blocks somatosensory-evoked potentials *(Invited Paper)*, Nathan McDannold, Yongzhi Zhang, Chanikarn Power, Costas Arvanitis, Natalia Vykhodtseva, Brigham and Women's Hospital (USA); Margaret Livingstone, Harvard Medical School (USA) . . . . [9467-16]

Ultrasound-based biomodulation mechanisms, devices and applications in medicine *(Invited Paper)*, George K. Lewis, ZetrOZ, Inc. (USA). . . . . . . [9467-17]

SESSION 3 . . . . MON 3:40 PM TO 4:40 PM

Low-intensity Energy Delivery for Biomodulation II

Joint Session with Conferences 9467 and 9460

Session Chair: **Richard Conroy,** National Institutes of Health (USA)

Antimicrobial blue light therapy for microbial wound infections *(Invited Paper)*, Tianhong Dai, Massachusetts General Hospital (USA) and Harvard Medical School (USA) . . . . [9467-18]

Therapeutic efficacy of photobiomodulation for the treatment of autoimmune demyelination *(Invited Paper)*, Jeri-Anne Lyons, Univ. of Wisconsin-Milwaukee (USA) . . . . [9467-19]

CONFERENCE 9467

Red/near-infrared light-emitting diode therapy for traumatic brain injury *(Invited Paper)*, Margaret A. Naeser, VA Boston Healthcare System (USA); Paula I. Martin, Michael Ho, Maxine H. Krengel, Yelena Bogdanova, VA Boston Healthcare System (USA) and Boston Univ. School of Medicine (USA); Jeffrey A. Knight, VA Boston Healthcare System (USA); Megan K. Yee, VA Boston Healthcare System (USA) and Boston Univ. School of Public Health (USA); Ross Zafonte, Spaulding Rehabilitation Hospital (USA) and Harvard Medical School (USA); Judith A. Frazier, Spaulding Rehabilitation Hospital (USA); Michael R. Hamblin, Wellman Ctr. for Photomedicine (USA) and Harvard Medical School (USA); Bang-Bon Koo, Boston Univ. (USA). . . . . [9467-20]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 4 . . . . TUE 8:00 AM TO 9:50 AM

Beyond Graphene Layered Materials and Devices

Session Chair: **Thomas George,** ChromoLogic, LLC (USA)

Van der Waals Solids: materials properties, synthesis and device applications *(Invited Paper)*, Anupama B. Kaul, The Univ. of Texas at El Paso (USA) . . . . [9467-21]

Beyond graphene layered materials and devices *(Invited Paper)*, Joshua A. Robinson, The Pennsylvania State Univ. (USA) . . . . [9467-22]

Synthesis, properties, and applications of group IV graphane analogues *(Invited Paper)*, Joshua Goldberger, The Ohio State Univ. (USA) . . . . . . [9467-23]

Phase engineering in 2D materials *(Invited Paper)*, Manish Chhowalla, Rutgers, The State Univ. of New Jersey (USA) . . . . [9467-24]

Challenges and opportunities in 2D crystals: graphene and beyond *(Invited Paper)*, Huili G. Xing, Cornell Univ. (USA) and Univ. of Notre Dame (USA) . . . . [9467-25]

SESSION 5 . . . . TUE 10:20 AM TO 12:30 PM

Graphene and 2D Electronics and Optoelectronics

Session Chair: **Kyung-Ah Son,** HRL Labs., LLC (USA)

2D electronic materials for army applications *(Invited Paper)*, Philip Perconti, U.S. Army Research Lab. (USA) . . . . [9467-26]

Two-dimensional materials synthesis and integration for low power and high frequency devices *(Invited Paper)*, Joshua A. Robinson, Suman Datta, The Pennsylvania State Univ. (USA) . . . . [9467-27]

Increasing the lego of 2D electronics materials: silicene and germanene, graphene's new synthetic cousins *(Invited Paper)*, Guy Le Lay, Aix-Marseille Univ. (France) . . . . [9467-28]

High-speed nanoelectronics based on graphene and beyond *(Invited Paper)*, Shu-Jen Han, IBM Thomas J. Watson Research Ctr. (USA). . . . . [9467-29]

Graphene and beyond: two-dimensional materials for transistor applications *(Invited Paper)*, Frank Schwierz, Technische Univ. Ilmenau (Germany) . . . . [9467-30]

2D materials for high-performance electronic, photonic and sensing applications *(Invited Paper)*, Steven J. Koester, Univ. of Minnesota, Twin Cities (USA) . . . . [9467-31]

Lunch/Exhibition Break . . . . 12:30 pm to 1:30 pm

SESSION 6 . . . . TUE 1:30 PM TO 4:10 PM

Surface Enhanced Spectroscopies for Ultrasensitive Sensing

Session Chair: **Aykutlu Dana,** Bilkent Univ. (Turkey)

Nanotechnology meets biology in the cancer cell *(Invited Paper)*, Mostafa A. El-Sayed, Georgia Institute of Technology (USA) . . . . [9467-32]

Super resolution imaging and SERS *(Invited Paper)*, Katherine A. Willets, The Univ. of Texas at Austin (USA) and Temple Univ. (USA) . . . . [9467-33]

Nanoplasmonic and metamaterials concepts for broadband surface enhanced sensing *(Invited Paper)*, Stefan A. Maier, Imperial College London (United Kingdom). . . . . [9467-34]

A computational look at nano-scale toward giga-pixel nanoscopy *(Invited Paper)*, Aydogan Ozcan, Univ. of California, Los Angeles (USA) . . . . [9467-36]

Opto-electro-mechanical biosensor enabled by graphene *(Invited Paper)*, Ertugrul Cubukcu, Alexander Y. Zhu, Fei Yi, Univ. of Pennsylvania (USA) . . . . [9467-37]

Laser phototherapy: the future of medicine, Terrance L. Baker, Sollay Cosmetic Medical & Laser Ctr. (USA) . . . . [9467-120]

SESSION 7 . . . . TUE 4:10 PM TO 5:30 PM

Novel Nanophotonic Devices, Sensors, and Concepts Based on 2D Materials

Session Chair: **Ertugrul Cubukcu,** Univ. of Pennsylvania (USA)

2D materials and heterostructures for applications in optoelectronics *(Invited Paper)*, Thomas Mueller, Technische Univ. Wien (Austria) . . . . . [9467-38]

Plasmon excitations in low dimensional graphitic materials *(Invited Paper)*, Feng Wang, Univ. of California, Berkeley (USA) . . . . [9467-39]

Optics and optoelectronics of 2D atomic membranes *(Invited Paper)*, Xiaobo Yin, Univ. of Colorado at Boulder (USA) . . . . [9467-40]

Graphene optoelectronic devices for optical communications and imaging *(Invited Paper)*, Dirk R. Englund, Ren-Jye Shiue, Massachusetts Institute of Technology (USA); Yuanda Gao, James Hone, Columbia Univ. (USA). . [9467-41]

Wednesday 22 April

SESSION 8 . . . . WED 8:00 AM TO 10:10 AM

Origami: Where Art, Devices, and Structures Merge

Session Chair: **Richard Vaia,** Air Force Research Lab. (USA)

Origami: folding in nature, art and technology *(Invited Paper)*, Joycelyn S. Harrison, Air Force Office of Scientific Research (USA) . . . [9467-42]

Bringing physics into the fold: Origami-inspired mechanical meta-materials *(Invited Paper)*, Itai Cohen, Cornell Univ. (USA) . . . . [9467-43]

Design tools for adaptive Origami devices *(Invited Paper)*, Philip Buskohl, Kazuko Fuchi, James J. Joo, Greg W. Reich, Richard Vaia, Air Force Research Lab. (USA) . . . . [9467-44]

A novel reconfigurable Origami spiral antenna utilizing 3D printing technologies *(Invited Paper)*, Manos M. Tentzeris, Christy Saintsing, Georgia Institute of Technology (USA) . . . . [9467-45]

popupCAD: a tool for automated design, fabrication, and analysis of laminate micro-devices *(Invited Paper)*, Daniel M. Aukes, Robert J. Wood, Harvard Univ. (USA) and Wyss Institute for Biologically Inspired Engineering (USA) . . . . [9467-46]

Origami compliant mechanisms and deployable space structures *(Invited Paper)*, Larry L. Howell, Spencer P. Magleby, Shannon A. Zirbel, Ezekiel G. Merriam, Brigham Young Univ. (USA); Robert J. Lang, Lang Origami (USA); Brian P. Trease, Jet Propulsion Lab. (USA). . . . . [9467-47]

DEDICATED EXHIBITION TIME AND LUNCH BREAK . . . . 10:10 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 9 . . . . WED 1:00 PM TO 2:50 PM

Micro- and Nano-Sensors and Materials for Oil and Gas Applications

Session Chair: **Joyce Wong,** California Institute of Technology (USA)

Industry-first field trial of inter-well reservoir nanoagent tracers *(Invited Paper)*, Mazen Kanj, Saudi Aramco (Saudi Arabia). . . . . [9467-48]

Application of nanotechnology to drilling fluids: How close are we? *(Invited Paper)*, James E. Friedheim, M-I SWACO (USA). . . . . [9467-49]

Autonomous micro and nano sensors for upstream oil and gas *(Invited Paper)*, David Chapman, The Univ. of Texas at Austin (USA); Walter J. Trybula, The Trybula Foundation, Inc. (USA) . . . . [9467-50]

CMOS methods for the creation of novel sensors for down-hole and surface applications *(Invited Paper)*, Sameer Walavalkar, Chieh-Feng Chang, Axel Scherer, California Institute of Technology (USA) . . . . [9467-51]

Diamond photonics: towards sensing applications in harsh environments *(Invited Paper)*, Marko Loncar, Harvard School of Engineering and Applied Sciences (USA) . . . . [9467-52]

SESSION 10 . . . . WED 3:30 PM TO 5:40 PM

Novel Harsh Environment Sensors for Energy Applications

Joint Session with Conferences 9467 and 9491

Session Chair: **Michael P. Buric,** National Energy Technology Lab. (USA)

Functional sensor material enabled harsh environment, high temperature optical sensors for energy applications *(Invited Paper)*, Paul R. Ohodnicki Jr., National Energy Technology Lab. (USA) . . . . [9467-53]

Ultra-high temperature fiber optical chemical sensors based on nano-porous metal oxides *(Invited Paper)*, Kevin P. Chen, Univ. of Pittsburgh (USA) . . . . [9467-54]

Phosphor-based fiber optic temperature sensors for harsh environments *(Invited Paper)*, Nicholas Djeu, Yutaka Shimoji, MicroMaterials, Inc. (USA) . . . . [9467-55]

Development of Laser induced breakdown spectroscopy (LIBS) sensor to assess groundwater quality impacts *(Invited Paper)*, Dustin McIntyre, Jinesh Jain, Cantwell Carson, Christian Goueguel, National Energy Technology Lab. (USA) . . . . [9467-56]

Temperature dependence of hydrogen related absorption in silica glass optical fibers at high temperatures *(Invited Paper)*, Elizabeth A. Bonnell, Li Yu, Daniel Homa, Virginia Tech Ctr. for Photonics Technology (USA) . . . . . [9467-57]

Analysis of the coupling optical fiber ultrasonic sensor for partial discharges detection, Fengmei F. Li, Yiying Liu, Linjie Wang, Chen Yu, Xi'an Jiaotong Univ. (China) . . . . [9491-15]

Thursday 23 April

SESSION 11 . . . . THU 8:30 AM TO 10:10 AM

MAST: Bio-inspired Control

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Hummingbird flight control under extreme aerodynamic circumstances *(Invited Paper)*, Robert Dudley, Univ. of California, Berkeley (USA) . . . . [9467-58]

A control theoretic approach to neuromorphic computing *(Invited Paper)*, Michael Dorothy, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9467-59]

Bio-inspired sensing and control for disturbance rejection and stabilization *(Invited Paper)*, Gregory Gremillion, James S. Humbert, Univ. of Maryland, College Park (USA) . . . . [9467-60]

High-speed autonomous navigation of unknown environments using learned probabilities of collision *(Invited Paper)*, Charles Richter, Nicholas Roy, Massachusetts Institute of Technology (USA) . . . . [9467-61]

Detecting discrete phenomena using wide field integration methods *(Invited Paper)*, Allison M. Mathis, Joseph K. Conroy, William D. Nothwang, Ryan Robinson, Jared Shamwell, U.S. Army Research Lab. (USA). . . . . [9467-62]

SESSION 12 . . . . THU 10:40 AM TO 12:00 PM

MAST: Scale Legged Locomotion

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Dynamic legged locomotion for palm-size robots *(Invited Paper)*, Ronald Fearing, Duncan Haldane, Univ. of California, Berkeley (USA); David Zarrouk, Ben-Gurion Univ. of the Negev (Israel) . . . . [9467-63]

Metastable legged locomotion in real-world environments: methods to quantify and optimize reliability *(Invited Paper)*, Katie Byl, Cenk O. Saglam, Univ. of California, Santa Barbara (USA). . . . . [9467-64]

Scattering of a legged robot in a heterogeneous granular terrain *(Invited Paper)*, Feifei Qian, Daniel I. Goldman, Georgia Institute of Technology (USA) . . . . [9467-65]

Data driven models of legged locomotion *(Invited Paper)*, Shai Revzen, Univ. of Michigan (USA) . . . . [9467-66]

Lunch/Exhibition Break . . . . Thu 12:00 pm to 1:00 pm

SESSION 13. . . . . THU 1:00 PM TO 2:50 PM

Novel Beam Control Applications and Techniques

Session Chairs: **Christopher C. Wilcox,** U.S. Naval Research Lab. (USA); **Matthew E. L. Jungwirth,** Honeywell Automation & Control Solutions (USA)

Real-time atmospheric imaging and processing with advanced adaptive optics and algorithm acceleration systems *(Invited Paper)*, Jony J. Liu, Leonid A. Beresnev, John E. McElhenny, Gary W. Carhart, U.S. Army Research Lab. (USA); Fouad E. Kiamilev, Univ. of Delaware (USA) . . . . [9467-67]

Ultraspectral imaging and the snapshot advantage *(Invited Paper)*, Michael W. Kudenov, Subharup Gupta Roy, Bryan D. Maione, North Carolina State Univ. (USA) . . . . [9467-68]

Design and characterization of a tunable opto-mechatronic system to mimic the focusing and the regulation of illumination in the formation of images made by the human eye *(Invited Paper)*, Agustín Santiago-Alvarado, Angel S. Cruz-Félix, Arturo Hernández Méndez, Yara Pérez-Maldonado, Cristian Dominguez Osante, Univ. Tecnológica de la Mixteca (Mexico) . . . . [9467-69]

Selective broadband jitter mitigation for non-common path errors *(Invited Paper)*, Edwin S. Ahn, Richard A. Carreras, Air Force Research Lab. (USA); Steve Gibson, Univ. of California, Los Angeles (USA) . . . . [9467-70]

Beam optimization for imaging lidar *(Invited Paper)*, Lyle Ruppert, Ball Aerospace & Technologies Corp. (USA) . . . . [9467-71]

CONFERENCE 9467

SESSION 14 . . . . THU 3:20 PM TO 5:00 PM

Photonics Research at SPAWAR

Session Chair: **Ryan P. Lu,**
Space and Naval Warfare Systems Command (USA)

Photonic RF-IF wideband down conversion using optical injection locking *(Invited Paper)*, James R. Adleman, SPAWAR Systems Ctr. (USA); Chunyan Lin, Space and Naval Warfare Systems Command (USA); Shai Barak Jester, B. Melvin L. Pascoguin, Douglass Evans, SPAWAR Systems Ctr. (USA); Everett W. Jacobs, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9467-72]

Wideband RF channelizer based on parametric combs *(Invited Paper)*, Sanja Zlatanovic, Space and Naval Warfare Systems Command (USA) . . . . . [9467-73]

Optical channel characterization in maritime atmospheres *(Invited Paper)*, Stephen M. Hammel, Dimitri Tsintikidis, John S. deGrassie, Colin Reinhardt, Kevin M. McBryde, Eric Hallenborg, David T. Wayne, Kristofor Gibson, Galen Cauble, Ana Ascencio, Joshua J. Rudiger, Space and Naval Warfare Systems Command (USA) . . . . [9467-74]

Wavelength optimization via retroreflection for underwater free-space optical communication *(Invited Paper)*, Burton Neuner III, B. Melvin L. Pascoguin, SPAWARSYSCEN Pacific: San Diego (USA) . . . . [9467-75]

Preparation of novel HTS films and tunnel junctions for advanced C3I sensor applications *(Invited Paper)*, Benjamin J. Taylor, Teresa H. Emery, Susan A. E. Berggren, Anna M. Leese de Escobar, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9467-76]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Lowering contact resistance of graphene FETs with capacitive extension of ohmic contacts for enhanced RF performance, Chowdhury G. Al-Amin, Mustafa Karabiyik, Raju Sinha, Nezih Pala, Florida International Univ. (USA) . . . . [9467-103]

Development of small-sized accelerometer, Sergey P. Timoshenkov, Andrey Mikheev, Alexey Timoshenkov, National Research Univ. of Electronic Technology (Russian Federation) . . . . [9467-104]

Comb structure analysis of the capacitive sensitive element in MEMS-accelerometer, Sergey P. Timoshenkov, Andrey Shalimov, Mikhail Golovinskiy, National Research Univ. of Electronic Technology (Russian Federation) . . . . [9467-105]

A bimorph electrothermal actuator for micromirror devices, Sergey Evstafyev, Sergey P. Timoshenkov, Igor Britkov, National Research Univ. of Electronic Technology (Russian Federation) . . . . [9467-106]

A novel class of MEMS accelerometers for guidance and control of gun-fired munitions, Jahangir Rastegar, Dake Feng, Omnitek Partners, LLC (USA); Carlos M. Pereira, U.S. Army Armament Research, Development and Engineering Ctr. (USA). . . . . [9467-108]

Fiber-based split-ring-resonators: producing strong magnetic response in the IR through an electrospinning technique, Tao Gong, Jeremy N. Munday, Univ. of Maryland, College Park (USA) . . . . [9467-109]

Thermal conductivity characterization of in-situ fabricated polysilicon nanowires for uncooled thermoelectric infrared detectors, Mohammad J. Modarres-Zadeh, Univ. of Central Florida (USA); Nahida Akhter, Intel Corp. (USA); Reza Abdolvand, Univ. of Central Florida (USA) . . . . [9467-110]

Two-photon absorption based optical logic, Xiang Zhang, Wenbo Li, Hongyu Hu, Niloy K. Dutta, Univ. of Connecticut (USA). . . . . [9467-111]

Mode-locked fiber ring laser using graphene as saturable absorber, Hongyu Hu, Xiang Zheng, Wenbo Li, Niloy K. Dutta, Univ. of Connecticut (USA) . . . . [9467-112]

Characterization of planar 6×6 cm2 MCP-based picosecond photo-detectors, Jingbo Wang, Karen Byrum, Marcel Demarteau, Edward A. May Jr., Robert G. Wagner, Dean Walters, Lei Xia, Junqi Xie, Huyue Zhao, Argonne National Lab. (USA) . . . . [9467-113]

Surface depletion mediated quantum dots, Walter R. Buchwald, Yeshaya Koblick, Univ. of Massachusetts Boston (USA) . . . . [9467-114]

Sensors application using microcontroller, Huthaifa A. Al Issa, Univ. of Dayton (USA) . . . . [9467-115]

Super resolution infrared light field imaging using single carbon nanotube detector, Ning Xi, Michigan State Univ. (USA) . . . . [9467-116]

High mobility single-crystalline-like semiconductor thin films on flexible metal substrates, Venkat Selvamanickam, Pavel Dutta, Ying Gao, Yao Yao, Monika Rathi, Univ. of Houston (USA) . . . . [9467-119]

Friday 24 April

SESSION 15 . . . . FRI 8:00 AM TO 8:30 AM

Keynote Session

Session Chair: **Michael K. Rafailov**

High power lasers for infrared countermeasures, targeting and illumination, beacons and standoff detection of explosives and CWAs *(Invited Paper)*, C. Kumar N. Patel, Pranalytica, Inc. (USA) . . . . [9467-77]

SESSION 16 . . . . FRI 8:30 AM TO 9:50 AM

Ultra-fast Bandgap Photonics

Session Chair: **Michael K. Rafailov**

Detector response to high repetition rate ultra-short laser pulses *(Invited Paper)*, Jason M. Auxier, U.S. Naval Research Lab. (USA); Myron P. Pauli, Naval Research Laboratory (USA); Michael K. Rafailov, DHPC Technologies (USA) and Univ. of Alberta (Canada); Michael K. Rafailov, DHPC Technologies, Inc (USA) . . . . [9467-78]

2-micron ultra-short pulse lasers *(Invited Paper)*, Shibin Jiang, AdValue Photonics, Inc. (USA) . . . . [9467-79]

Ultrafast fiber lasers: practical applications *(Invited Paper)*, Igor Pastirk, TOPTICA Photonics Inc. (USA); Alexander Sell, Robert Herda, Andreas Brodschelm, Armin Zach, TOPTICA Photonics AG (Germany). . . . . [9467-80]

Plasmonic nanoantennas for enhanced midwave and longwave infrared imaging *(Invited Paper)*, David W. Peters, Thomas E. Beechem III, Stephen W. Howell, Jin K. Kim, Darin Leonhardt, Joel R. Wendt, John A. Montoya, Sandia National Labs. (USA) . . . . [9467-81]

SESSION 17. . . . . FRI 10:20 AM TO 12:20 PM

THz Photonics

Session Chair: **Michael K. Rafailov**

Terahertz electronics for sensing and imaging applications *(Invited Paper)*, Michael Shur, Rensselaer Polytechnic Institute (USA) . . . . [9467-82]

A compact THz imaging set-up at 750 microns *(Invited Paper)*, Linda E. Marchese, Marc Terroux, Alain Bergeron, INO (Canada) . . . . [9467-83]

Collection Efficiency for Millimeter and Submillimeter Wave Antenna-coupled DetectionCollection efficiency for millimeter and submillimeter wave antenna-Collection efficiency for millimeter and submillimeter wave antenna-coupled detection *(Invited Paper)*, Brian A. Lail, Yuancheng Xu, Florida Institute of Technology (USA) . . . . [9467-84]

CMOS mm-wave system-on-chip for sensing and communication *(Invited Paper)*, Adrian J. Tang, Jet Propulsion Lab. (USA) and Univ. of California, Los Angeles (USA) . . . . [9467-85]

Applications and challenges for MMW and THz sensors *(Invited Paper)*, John N. Sanders-Reed, The Boeing Co (USA) . . . . [9467-86]

Video rate imaging at 1.5 THz via frequency upconversion to the near-IR *(Invited Paper)*, Patrick F. Tekavec, Vladimir G. Kozlov, Ian McNee, Microtech Instruments, Inc. (USA); Yun-Shik Lee, Oregon State Univ. (USA); Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9467-87]

Lunch Break . . . . 12:20 pm to 1:30 pm

SESSION 18 . . . . FRI 1:30 PM TO 3:10 PM

Mid-IR Laser Photonics

Session Chair: **Michael K. Rafailov**

Solution-processed chalcogenide glass: a pathway toward novel materials and architectures for mid-IR photonics *(Invited Paper)*, Craig B. Arnold, TAG Optics, Inc. (USA) . . . . [9467-88]

Approaches to generation of tunable mid-IR ultrafast pulses with fiber sources *(Invited Paper)*, Alexander Sell, TOPTICA Photonics AG (Germany); Igor Pastirk, TOPTICA Photonics Inc. (USA); Alexander Sell, Andreas Brodschelm, Robert Herda, TOPTICA Photonics AG (Germany); Thomas Puppe, TOPTICA Photonics Inc. (Germany); Armin Zach, TOPTICA Photonics AG (Germany) . . . . . [9467-89]

Long wavelength mid-infrared from mixing two colors from a fiber amplifier *(Invited Paper)*, Donna Strickland, Univ. of Waterloo (Canada). . . . . [9467-90]

Mid-infrared ultrafast fiber laser *(Invited Paper)*, Peng Wan, Lih-Mei Yang, Jian Liu, PolarOnyx, Inc. (USA) . . . . [9467-91]

Mid-IR lasers based on transition metal doped II-VI semiconductors *(Invited Paper)*, Sergey B. Mirov, The Univ. of Alabama at Birmingham (USA) and IPG Photonics - Mid-Infrared Lasers (USA); Vladimir V. Fedorov, Dmitry V. Martyshkin, The Univ. of Alabama at Birmingham (USA); Igor S. Moskalev, Mike B. Mirov, Sergey Vasilyev, IPG Photonics - Mid-Infrared Lasers (USA); Valentin P. Gapontsev, IPG Photonics Corp. (USA) . . . . [9467-92]

SESSION 19 . . . . FRI 3:30 PM TO 4:00 PM

Quantum Cascade Lasers and Spectroscopy

Session Chair: **Michael K. Rafailov**

Quantum cascade laser frequency combs for spectroscopy *(Invited Paper)*, Jérôme Faist, ETH Zürich (Switzerland) . . . . [9467-93]

SESSION 20 . . . . FRI 4:00 PM TO 6:00 PM

Laser Chemical Detection

Joint Session with Conferences 9467, 9455, 9486

Session Chair: **Michael K. Rafailov,** The Reger Group (USA)

Broadband mid-IR frequency comb source for standoff chemical detection *(Invited Paper)*, Konstantin L. Vodopyanov, CREOL, The College of Optics and Photonics, Univ. of Central Florida (USA) . . . . [9467-94]

Standoff trace detection of explosives with Infrared hyperspectral imagery *(Invited Paper)*, Frank Fuchs, Stefan Hugger, Jan-Philip Jarvis, Quankui K. Yang, Ralf Ostendorf, Christian Schilling, Wolfgang Bronner, Raschid Driad, Rolf Aidam, Joachim Wagner, Fraunhofer-Institut für Angewandte Festkörperphysik (Germany) . . . . [9467-95]

Spectral shifted background references for QCL based mid infrared standoff spectroscopy *(Invited Paper)*, Charles W. Van Neste, Thomas G. Thundat, Univ. of Alberta (Canada) . . . . [9467-96]

Toward the realization of a compact chemical sensor platform using quantum cascade lasers *(Invited Paper)*, Ellen L. Holthoff, Paul M. Pellegrino, Logan S. Marcus, U.S. Army Research Lab. (USA) . . . . [9467-97]

Detection of trace explosives on relevant substrates using a mobile platform for photothermal infrared imaging spectroscopy (PT-IRIS) *(Invited Paper)*, Christopher A. Kendziora, Robert Furstenberg, Michael R. Papantonakis, Viet Nguyen, Jeff M. Byers, R. Andrew McGill, U.S. Naval Research Lab. (USA) . . . . [9467-98]

Standoff detection of chemical and biological threats using miniature widely tunable QCLs *(Invited Paper)*, Petros Kotidis, Erik R. Deutsch, Anish K. Goyal, Block Engineering, LLC (USA) . . . . [9467-99]

SESSION 21 . . . . FRI 6:00 PM TO 7:00 PM

Quantum Cascade Lasers

Joint Session with Conferences 9467, 9455, 9486

Session Chair: **Michael K. Rafailov,** The Reger Group (USA)

Recent progress in quantum cascade external cavity laser systems optimized for mid-IR sensing applications *(Invited Paper)*, David B. Arnone, Leigh J. Bromley, David B. Caffey, William B. Chapman, Timothy Day, Allen Priest, Daylight Solutions Inc. (USA); Charles C. Harb, The Univ. of New South Wales (Australia) . . . . [9467-100]

Recent results on performance optimization of QCLs for consumption, spectral coverage and power *(Invited Paper)*, Antoine Müller, Richard Maulini, Stéphane Blaser, Alfredo Bismuto, Tobias Gresch, Romain Terazzi, Alpes Lasers SA (Switzerland) . . . . [9467-101]

High power MWIR quantum cascade lasers and their use in intra-cavity THz room temperature generation *(Invited Paper)*, Mariano Troccoli, AdTech Optics, Inc. (USA) . . . . [9467-102]

CONFERENCE 9468

Tuesday–Thursday 21–23 April 2015 • Proceedings of SPIE Vol. 9468

Unmanned Systems Technology XVII

Conference Chairs: **Robert E. Karlsen,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA); **Douglas W. Gage,** XPM Technologies (USA); **Charles M. Shoemaker,** U.S. Army Communications-Electronics Research Development and Engineering Command (USA); **Grant R. Gerhart,** U.S. Army Tank-Automotive Research, Development, and Engineering Ctr.-Retired (USA)

Program Committee: **Jonathan A. Bornstein,** U.S. Army Research Lab. (USA); **Jared Giesbrecht,** Defence Research and Development Canada, Suffield (Canada); **Frank L. Lewis,** The Univ. of Texas at Arlington (USA); **Larry H. Matthies,** Jet Propulsion Lab. (USA); **Camille S. Monnier,** Charles River Analytics, Inc. (USA); **Paul L. Muench,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA); **Hoa G. Nguyen,** Space and Naval Warfare Systems Ctr. Pacific (USA); **James L. Overholt,** Air Force Research Lab. (USA); **Mike Perschbacher,** RovnoTech (USA); **Anthony Stentz,** Carnegie Mellon Univ. (USA); **Gary Witus,** Turing Associates, Inc. (USA); **Brian M. Yamauchi,** iRobot Corp. (USA)

Tuesday 21 April

SESSION 1. . . . . TUE 1:00 PM TO 3:00 PM

Perception and Human Robot Interaction

Session Chairs: **Camille S. Monnier,** Charles River Analytics, Inc. (USA); **Hoa G. Nguyen,** Space and Naval Warfare Systems Ctr. Pacific (USA)

Multi-modal interaction for UAS control, Glenn Taylor, Ben Purman, Paul Schermerhorn, Guillermo Garcia-Sampedro, Robert Hubal, Soar Technology, Inc. (USA); Kathleen Crabtree, Booz Allen Hamilton Inc. (USA) . . . . [9468-1]

A novel method for full position and angular orientation measurement of moving objects, Harbans S. Dhadwal, Jahangir Rastegar, Dake Feng, Philip Kwok, Omnitek Partners, LLC (USA). . . . . [9468-2]

Towards contextual awareness in robot mapping: extracting semantic hierarchy from point cloud data, Carlos P. Nieto-Granda, Siddharth Choudhary, Georgia Institute of Technology (USA); John G. Rogers III, Jeffrey N. Twigg, U.S. Army Research Lab. (USA); Varun Murali, Henrik I. Christensen, Georgia Institute of Technology (USA) . . . . [9468-3]

Natural interaction for unmanned systems, Glenn Taylor, Soar Technology, Inc. (USA). . . . . [9468-4]

Fusion of lidar and radar for detection of partially obscured objects, Jim Hollinger, Brett Kutscher, LSA Autonomy LLC (USA); Ryan R. Close, U.S. Army RDECOM CERDEC NVESD (USA) . . . . [9468-5]

3D environment modeling on uneven-terrain using 3D LIDAR and IMU for unmanned ground system, Kuk Cho, Korea Institute of Industrial Technology (Korea, Republic of); Muhammad Ilyas, Univ. of Science and Technology (Korea, Republic of); SeungHo Baeg, Sangdeok Park, Korea Institute of Industrial Technology (Korea, Republic of) . . . . [9468-6]

SESSION 2 . . . . TUE 3:30 PM TO 5:10 PM

Robotics CTA

Session Chairs: **Jonathan A. Bornstein;** U.S. Army Research Lab. (USA); **Dilip G. Patel,** General Dynamics Research Systems (USA)

Motion compensation for structured light sensors, Christoph Mertz, Debjani Biswas, Carnegie Mellon Univ. (USA) . . . . [9468-7]

Active dictionary learning for image representation, Tong Wu, Anand Sarwate, Waheed U. Bajwa, Rutgers, The State Univ. of New Jersey (USA) . . . . [9468-8]

RCTA capstone assessment, Craig Lennon, Barry Bodt, U.S. Army Research Lab. (USA); Richard Camden, Engility Corp. (USA); Charles A. DiBerardino, General Dynamics Robotic Systems (USA); Marshal Childers, U.S. Army Research Lab. (USA) . . . . [9468-9]

Semi-autonomous exploration of multi-floor buildings with a legged robot, Garrett J. Wenger, Aaron M. Johnson, Camillo J. Taylor, Daniel E. Koditschek, Univ. of Pennsylvania (USA) . . . . [9468-10]

Stabilization and agility quantification of a flexible-spine bounding quadruped model, Katie Byl, Nadim Sarham, Tom Strizic, Chia-Chi Wu, Univ. of California, Santa Barbara (USA); Jason L. Pusey, U.S. Army Research Lab. (USA) . . . . [9468-11]

Wednesday 22 April

SESSION 3 . . . . WED 8:30 AM TO 10:30 AM

Self-organizing Collaborative Unmanned ISR Teams I

Joint Session with Conferences 9479 and 9468

Session Chairs: **Raja Suresh,** General Dynamics Advanced Information Systems (USA); **Robert E. Karlsen,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA)

DARPA perspective on open architectures *(Invited Paper)*, John Shaw, Defense Advanced Research Projects Agency (USA). . . . . [9479-14]

Open mission system overview *(Invited Paper)*, Eric Koper, U.S. Air Force (USA) . . . . [9479-15]

Overview of DARPA CODE program *(Invited Paper)*, Jean-Charles Lede, Defense Advanced Research Projects Agency (USA). . . . . [9479-16]

Open architecture flexible weapons *(Invited Paper)*, Jonathan Shaver, Air Force Research Lab. (USA). . . . . [9479-17]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:30 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 4 . . . . WED 1:00 PM TO 3:10 PM

Self-organizing, Collaborative Unmanned ISR Teams II

Joint Session with conferences 9479 and 9468

Session Chairs: **Raja Suresh,** General Dynamics Advanced Information Systems (USA); **Robert E. Karlsen,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA)

Executable architecture management system *(Invited Paper)*, Jeff Monroe, Metron, Inc. (USA) . . . . [9479-18]

UAV field demonstration of social media enabled tactical data link, Christopher C. Olson, Andrew J. Newman, Da Xu, Sean R. Martin, Jonathan C. Castelli, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . . . . [9468-12]

Fuel Cell powered small unmanned aerial systems (UASs) for extended endurance, Deryn D. Chu, Zachary Dunbar, Rongzhong Jiang, U.S. Army Research Lab. (USA) . . . . [9468-13]

Tactical 3D model generation using structure-from-motion on video from unmanned systems, Joshua D. Harguess, Mark Bilinski, Kim B. Nguyen, Darren N. Powell, Susie Alderson, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-14]

Aircraft path planning for optimal imaging using dynamic cost functions, Gordon Christie, Haseeb R. Chaudhry, Kevin Kochersberger, Virginia Polytechnic Institute and State Univ. (USA) . . . . [9468-15]

UxV to the cloud via widgets, Michael August, Darren N. Powell, Charles Yetman, Kim B. Nguyen, Joshua D. Harguess, Mark Bilinski, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-16]

SESSION 5 . . . . WED 3:40 PM TO 6:00 PM

Special Topics

Session Chairs: **Douglas W. Gage,** XPM Technologies (USA); **Charles M. Shoemaker,** U.S. Army Communications-Electronics Research Development and Engineering Command (USA)

Construction robots for Mars, Douglas W. Gage, XPM Technologies (USA) . . . . [9468-17]

Research for a multi-modal mobility and manipulation propulsion core, Harris L. Edge, U.S. Army Research Lab. (USA). . . . . [9468-18]

Automatic pose sensing for an IED-detecting dog, Hoa G. Nguyen, Adam F. Nans, Kurt A. Talke, Paul Candela, H. R. Everett, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-19]

Incremental learning in trust-based vehicle control, Dariusz G. Mikulski, Robert E. Karlsen, U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA). . . . . [9468-20]

Differences in cyber security considerations for remotely piloted and autonomous unmanned aerial vehicles, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9468-21]

Design and experimental validation of a simple controller for a multi-segment magnetic crawler robot, Leah Kelley, Massachusetts Institute of Technology (USA); Saam Ostovari, Aaron B. Burmeister, Kurt A. Talke, Narek Pezeshkian, Hoa G. Nguyen, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-22]

The role of C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) in expedited deployment of autonomous UGV's, Charles M. Shoemaker, U.S. Army Communications-Electronics Research Development and Engineering Command (CERDEC) (USA) . . . . [9468-23]

Thursday 23 April

SESSION 6 . . . . THU 8:30 AM TO 10:10 AM

MAST: Bio-inspired Control

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Hummingbird flight control under extreme aerodynamic circumstances *(Invited Paper)*, Robert Dudley, Univ. of California, Berkeley (USA) . . . . [9467-58]

A control theoretic approach to neuromorphic computing *(Invited Paper)*, Michael Dorothy, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9467-59]

Bio-inspired sensing and control for disturbance rejection and stabilization *(Invited Paper)*, Gregory Gremillion, James S. Humbert, Univ. of Maryland, College Park (USA) . . . . [9467-60]

High-speed autonomous navigation of unknown environments using learned probabilities of collision *(Invited Paper)*, Charles Richter, Nicholas Roy, Massachusetts Institute of Technology (USA) . . . . [9467-61]

Detecting discrete phenomena using wide field integration methods *(Invited Paper)*, Allison M. Mathis, Joseph K. Conroy, William D. Nothwang, Ryan Robinson, Jared Shamwell, U.S. Army Research Lab. (USA) . . . . [9467-62]

SESSION 7 . . . . THU 10:40 AM TO 12:00 PM

MAST: Scale Legged Locomotion

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Dynamic legged locomotion for palm-size robots *(Invited Paper)*, Ronald Fearing, Duncan Haldane, Univ. of California, Berkeley (USA); David Zarrouk, Ben-Gurion Univ. of the Negev (Israel) . . . . [9467-63]

Metastable legged locomotion in real-world environments: methods to quantify and optimize reliability *(Invited Paper)*, Katie Byl, Cenk O. Saglam, Univ. of California, Santa Barbara (USA). . . . . [9467-64]

Scattering of a legged robot in a heterogeneous granular terrain *(Invited Paper)*, Feifei Qian, Daniel I. Goldman, Georgia Institute of Technology (USA) . . . . [9467-65]

Data driven models of legged locomotion *(Invited Paper)*, Shai Revzen, Univ. of Michigan (USA) . . . . [9467-66]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Open Space Box: communication to support big data in orbit, Atif F. Mohammad, Jeremy Straub, Univ. of North Dakota (USA) . . . . . [9468-24]

Stealth Technology: the potential to make the visible, invisible, Laura Samso Pericon, Consultant (Spain). . . . . [9468-25]

Kestrel vidar, Simon Olsen, Sentient Vision Systems Pty Ltd. (Australia). . . . . [9468-26]

CONFERENCE 9469

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9469

Sensors and Systems for Space Applications VIII

Conference Chairs: **Khanh D. Pham,** Air Force Research Lab. (USA); **Genshe Chen,** Intelligent Fusion Technology, Inc. (USA)

Program Committee: **Joseph L. Cox,** Missile Defense Agency (USA); **Erik P. Blasch,** Air Force Research Lab. (USA); **Trevor J. Bihl,** Air Force Institute of Technology (USA); **Brien Flewelling,** Air Force Research Lab. (USA); **Thomas George,** ChromoLogic (USA); **Richard T. Howard,** NASA Marshall Space Flight Ctr. (USA); **Brian K. McComas,** Raytheon Missile Systems (USA); **Jeremy Murray-Krezan,** Air Force Research Lab. (USA); **Tien M. Nguyen,** The Aerospace Corp. (USA); **Andre Samberg,** Sec-Control Finland Ltd. (Finland); **Robert SiVilli,** Air Force Research Lab. (USA); **Ryan M. Weisman,** Air Force Research Lab. (USA); **Henry Zmuda,** Univ. of Florida (USA)

Monday 20 April

SESSION 1. . . . . MON 8:30 AM TO 11:20 AM

Space Payload Technologies

Session Chairs: **Brien R. Flewelling,** Air Force Research Lab. (USA); **Joseph L. Cox,** Missile Defense Agency (USA)

Correction of active space telescope mirror using woofer-tweeter adaptive optics, Matthew R. Allen, Jae Jun Kim, Brij N. Agrawal, Naval Postgraduate School (USA) . . . . [9469-1]

Adaptive, realtime spectral imaging system with a digitally programmable matched filter function, J. Daniel Newman, Andrew P. Sacco, Angela M. D'Orazio, Eskander Ensafi, Exelis Geospatial Systems (USA); Yves Conturie, Exelis Inc. (USA); Steven Chien, Jet Propulsion Lab. (USA); Marek Kowarz, MicroAdventure Technologies LLC (USA); Paul P. K. Lee, George S. Brown, Exelis Geospatial Systems (USA); Ralph C. Short, Jeffrey Czajka, ITT Exelis (USA) . . . . [9469-2]

Characterizing point spread function fluctuations to improve resident space object detection, Tyler Hardy, Stephen C. Cain, Air Force Institute of Technology (USA) . . . . [9469-3]

High-resolution infrared detector and its electronic unit for space application, Mustapha Meftah, LATMOS (France). . . . . [9469-4]

Anomalous cases of astronaut helmet detection, Chester Dolph, NASA Langley Research Ctr. (USA) and Old Dominion Univ. (USA); Andrew J. Moore, NASA Langley Research Ctr. (USA); Matt Schubert, NASA Langley Research Ctr. (USA) and Christopher Newport Univ. (USA); Glenn Woodell, NASA Langley Research Ctr. (USA) . . . . [9469-5]

Program technical baseline framework for future space systems: a combined DoD acquisition, OSA and integrated program management perspective *(Invited Paper)*, Tien M. Nguyen, Andy T. Guillen, Sumner S. Matsunaga, The Aerospace Corp. (USA) . . . . [9469-6]

SESSION 2 . . . . MON 11:20 AM TO 12:00 PM

Cyber Physical System

Session Chairs: **Richard T. Howard,** NASA Marshall Space Flight Ctr. (USA); **Wei Yu,** Towson Univ. (USA)

Towards an integrated defense system for cyber security situation awareness, Hanlin Zhang, Zhijiang Chen, Wei Yu, Towson Univ. (USA); Sixiao Wei, Dan Shen, Genshe Chen, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Erik Blasch, Air Force Research Lab. (USA). . . . . [9469-7]

Internet threat monitoring (ITM) against localization attack using random delay addition, Sixiao Wei, Dan Shen, Intelligent Fusion Technology, Inc. (USA); Wei Yu, Chao Lu, Towson Univ. (USA); Erik Blasch, Khanh Pham, Air Force Research Lab. (USA); Genshe Chen, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-8]

Lunch Break . . . . .Mon 12:00 pm to 1:30 pm

SESSION 3 . . . . MON 1:30 PM TO 3:10 PM

Protected SATCOM and SatOP

Session Chairs: **Zhonghai Wang,** Intelligent Fusion Technology, Inc. (USA); **Xi Zhang,** Texas A&M Univ. (USA)

Quantum key distribution for QoS guarantee in satellite networks, Ping Wang, Xi Zhang, Texas A&M Univ. (USA); Genshe Chen, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Erik Blasch, Air Force Research Lab. (USA) . . . . [9469-9]

A probabilistic reasoning approach for communications satellite situational awareness, Todd Martin, Kuochu C. Chang, George Mason Univ. (USA); Xin Tian, Genshe Chen, Intelligent Fusion Technology, Inc. (USA). . . . . [9469-10]

Multi-carrier transmission for hybrid radio frequency with optical wireless communications, Gang Wang, Genshe Chen, Dan Shen, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Erik Blasch, Air Force Research Lab. (USA); Tien Nguyen, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-11]

RFI modeling and prediction approach for SATOP applications, Tien M. Nguyen, The Catholic Univ. of America (USA); Hien T. Tran, North Carolina State Univ. (USA); Zhonghai Wang, Genshe Chen, Gang Wang, Intelligent Fusion Technology, Inc. (USA); Steven A. Lane, Khanh Pham, Air Force Research Lab. (USA) . . . . [9469-12]

A TDMA MIMO SAR radar for automated position-keeping, Zhonghai Wang, Xingping Lin, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Erik Blasch, Air Force Research Lab. (USA); Genshe Chen, Dan Shen, Bin Jia, Gang Wang, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-13]

SESSION 4 . . . . MON 3:40 PM TO 4:40 PM

Positioning, Navigation, and Tracking

Session Chairs: **Trevor J. Bihl,** Air Force Institute of Technology (USA); **Bin Jia,** Intelligent Fusion Technology, Inc. (USA)

A benchmark for vehicle detection on wide area motion imagery, Joseph Catrambone, Ismail Amzovski, Temple Univ. (USA); Erik Blasch, Carolyn Sheaff, Air Force Research Lab. (USA); Genshe Chen, Intelligent Fusion Technology, Inc. (USA); Haibin Ling, Temple Univ. (USA). . . . . [9469-14]

Multi-target detection and estimation with the use of massive independent identical sensors, Tiancheng Li, Univ. de Salamanca (Spain) and Northwestern Polytechnical Univ. (China); Juan M. Corchado, Univ. de Salamanca (Spain); Javier Bajo, Univ. Politécnica de Madrid (Spain); Genshe Chen, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-15]

A suborbital IMU test mission, Adam R. Lawman, Jeremy Straub, Scott Kerlin, Univ. of North Dakota (USA) . . . . [9469-16]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 5 . . . . TUE 8:00 AM TO 11:10 AM

Space Situational Awareness

Session Chairs: **Erik Blasch,** Air Force Research Lab. (USA); **Dan Shen,** Intelligent Fusion Technology, Inc. (USA)

Review of game theory applications for situation awareness, Erik Blasch, Air Force Research Lab. (USA); Dan Shen, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Air Force Research Lab. (USA); Genshe Chen, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-17]

Pursuit-evasion games with information uncertainties for elusive orbital maneuver and space object tracking, Dan Shen, Bin Jia, Genshe Chen, Intelligent Fusion Technology, Inc. (USA); Erik Blasch, Khanh Pham, Air Force Research Lab. (USA) . . . . [9469-18]

Distributed sensor management for space situational awareness via a negotiation game, Bin Jia, Dan Shen, Intelligent Fusion Technology, Inc. (USA); Khanh Pham, Erik Blasch, Air Force Research Lab. (USA); Genshe Chen, Intelligent Fusion Technology, Inc. (USA) . . . . [9469-19]

Size distribution for orbital debris measured with the NASA-WISE Instrument, Jeremy Murray-Krezan, Air Force Research Lab. (USA) . . [9469-20]

Enabling direct feedback between initial orbit determination and sensor data processing for detection and tracking of space objects, Brien R. Flewelling, Air Force Research Lab. (USA); Bradley Sease, Virginia Polytechnic Institute (USA); Timothy S. Murphy, Georgia Institute of Technology (USA) . . . . [9469-21]

Space situational awareness applications for radio astronomy assets, Galen Watts, National Radio Astronomy Observatory (USA); John M. Ford, National Radio Astronomy Obseravtory (USA); H. Alyson Ford, National Radio Astronomy Observatory (USA) . . . . [9469-22]

The Joint Space Operations Center (JSpOC) Mission System (JMS) and Advanced Research, Collaboration, and Application Development Environment (ARCADE): a test bed for space situational awareness algorithms *(Invited Paper)*, Jeremy Murray-Krezan, Air Force Research Lab. (USA) . . . . [9469-23]

SESSION 6 . . . . TUE 11:10 AM TO 12:10 PM

Processing and Exploitation

Session Chairs: **Jeremy Murray-Krezan,** Air Force Research Lab. (USA); **Ryan M. Weisman,** Air Force Research Lab. (USA)

Economic analysis of open space box model utilization in space craft, Atif F. Mohammad, The Univ. of North Dakota (USA); Jeremy Straub, Univ. of North Dakota (USA). . . . . [9469-24]

The effects of developments in the stealth technology, passive radars and optic sensors on the future, Asim Göktas, Turkish War College (Turkey) . . . . [9469-25]

The Thermal Infrared Compact Imaging Spectrometer (TIRCIS): a follow-on to the Space Ultra-Compact Hyperspectral Imager, Sarah T. Crites, Robert Wright, Paul G. Lucey, Jeremy Chan, Harold Garbeil, Amber Imai, Eric J. Pilger, Mark Wood, L. Yoneshige, Univ. of Hawai'I (USA) . . . . [9469-26]

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www.spie.org/dss15program

CONFERENCE 9470A

Wednesday–Thursday 22–23 April 2015 • Part of Proceedings of SPIE Vol. 9470

Display Technologies and Applications for Defense, Security, and Avionics IX

Conference Chairs: **Daniel D. Desjardins,** Consultant (USA); **Kalluri R. Sarma,** Honeywell Technology (USA)

Program Committee: **Masoud Ali,** Barco, Inc. (USA); **Hari M. Atkuri,** BEAM Engineering for Advanced Measurements Co. (USA); **Philip J. Bos,** Kent State Univ. (USA); **Alexander A. Cameron,** BAE Systems (United Kingdom); **Reginald Daniels,** Air Force Research Lab. (USA); **Timothy J. Edwards,** Kopin Corp. (USA); **Jean-Michel Francois,** Thales Avionics S.A. (France); **Gary W. Jones,** NanoQuantum Sciences, Inc. (USA); **Charles J. Lloyd,** Visual Performance, LLC (USA); **John P. McIntire,** Air Force Research Lab. (USA); **Raymond Schulze,** U.S. Army CERDEC CP&I Directorate (USA); **Joe Tchon,** Rockwell Collins, Inc. (USA); **Paul L. Wisely,** Holoeye Systems (USA)

Wednesday 22 April

SESSION 1. . . . . WED 3:30 PM TO 4:50 PM

Head and Helmet Mounted Displays and Display Technologies and Applications for Defense, Security, and Avionics

Joint Session with Conferences 9470A and 9470B

Session Chair: **Peter L. Marasco,** Air Force Research Lab. (USA)

Diver's full face mask head-up display using waveguide optical display technology, Dennis Gallagher, Richard Manley, Naval Surface Warfare Ctr. Panama City Div. (USA). . . . . [9470-1]

The impact of coloured symbology on cockpit eyes-out display effectiveness: a survey of key parameters, Maha Fares, Derek R. Jordan, BAE Systems (United Kingdom) . . . . [9470-35]

Augmented reality technology for heads-up, day/night situational awareness for the dismounted soldier, Eric Gans, Applied Research Associates, Inc. (USA). . . . . [9470-2]

Operational feedback on night vision with hyperstereoscopic HMD, Jean-Michel Francois, Thales Avionics S.A. (France); Daniel Maulet, Thales Angénieux S.A. (France); Joel Baudou, Thales Avionics S.A. (France) . . . [9470-3]

Thursday 23 April

SESSION 2 . . . . THU 8:00 AM TO 9:30 AM

Head-Mounted and Body-Worn Displays

Session Chair: **Kalluri R. Sarma,** Honeywell Technology (USA)

Review and current status of head-mounted display technologies *(Invited Paper)*, Hong Hua, College of Optical Sciences, The Univ. of Arizona (USA) . . . . [9470-4]

Keeping display visibility in outdoor environment, Ariela Donval, Ido E. Dotan, Noam Gross, Eran Partouche, Ofir Lipman, Moshe Oron, KiloLambda Technologies, Ltd. (Israel) . . . . [9470-5]

Investigation of the benefits of utilizing lidar-based data on wearable mobile computing platforms, Vince Schmidt, George A. Reis, Air Force Research Lab. (USA); Charlton Anderson, The Design Knowledge Co. (USA) . . . . [9470-6]

Wearable android controller for a telescope observatory system, Vince Schmidt, John Ianni, Air Force Research Lab. (USA) . . . . [9470-7]

SESSION 3 . . . . THU 9:30 AM TO 10:10 AM

Stereoscopic 3D Displays

Session Chair: **Reginald Daniels,** Air Force Research Lab. (USA)

3D display considerations for rugged airborne environments, Tracy J. Barnidge, Joseph L. Tchon, Rockwell Collins, Inc. (USA). . . . . [9470-8]

A guide for human factors research with stereoscopic 3D displays, John P. McIntire, Paul R. Havig II, Alan R. Pinkus, Air Force Research Lab. (USA) . . . . [9470-9]

SESSION 4 . . . . THU 10:40 AM TO 11:20 AM

Immersive Environments and Augmented Reality

Session Chair: **Jean-Michel Francois,** Thales Avionics S.A. (France)

Exploring immersive environments to aid urban intelligence, surveillance and reconnaissance operations, Jason Roll, Air Force Research Lab. (USA); Peter Venero, Infoscitex Corp. (USA); Donald Adkins, Air Force Research Lab. (USA); Sarah Lampke, Timothy MtCastle, Infoscitex Corp. (USA) . . . . . [9470-10]

Augmented reality enabling intelligence exploitation at the edge, Sue E. Kase, Elizabeth K. Bowman, Debra Patton, U.S. Army Research Lab. (USA) . . . . [9470-11]

SESSION 5 . . . . .THU 11:20 AM TO 12:00 PM

Increased Resolution Via Virtual Pixel

Session Chair: **Joseph L. Tchon,** Rockwell Collins, Inc. (USA)

A virtual pixel software and hardware technology to increase projector resolution, Jeremy Straub, Benjamin M. Kading, Univ. of North Dakota (USA) . . . . [9470-12]

A virtual pixel technology to enhance the resolution of monitors and for other purposes, Benjamin M. Kading, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9470-13]

Lunch/Exhibition Break . . . . .12:00 pm to 1:30 pm

SESSION 6 . . . . THU 1:30 PM TO 3:00 PM

Display Performance Research and Advances

Session Chair: **Gary W. Jones,** NanoQuantum Sciences, Inc. (USA)

Review of the evolution of display technologies for next generation aircraft *(Invited Paper)*, Joseph L. Tchon, Rockwell Collins, Inc. (USA) . . . . [9470-14]

A neuroergonomic quasi-experiment: predictors of situation awareness and display usability with USAF pilots while performing complex tasks, Steven D. Harbour, U.S. Air Force (USA); James C. Christensen, Air Force Research Lab. (USA) . . . . [9470-15]

A practical definition of eye-limited display system resolution, Charles J. Lloyd, Visual Performance, LLC (USA) . . . . [9470-16]

Just noticeable color difference: implications for display systems, Daniel D. Desjardins, Northrup Grumman (USA) . . . . [9470-17]

SESSION 7 . . . . THU 3:30 PM TO 4:20 PM

Flexible Displays

Session Chair: **Paul L. Wisely,**
HOLOEYE Systems Inc. (United Kingdom)

Recent advances in OLED and flexible displays and their potential for application to aerospace and military display systems *(Invited Paper)*, Kalluri R. Sarma, Honeywell Technology (USA) . . . . [9470-18]

Flexible displays for military applications, Jason T. Holmstedt, Physical Optics Corp. (USA) . . . . [9470-19]

SESSION 8 . . . . THU 4:20 PM TO 7:00 PM

Cornucopia

Session Chair: **Daniel D. Desjardins**

Analog video to ARINC 818, Paul Grunwald, Great River Technology, Inc. (USA) . . . . [9470-20]

Electro-textile garments for power and data distribution, Jeremiah Slade, Infoscitex Corp. (USA); Carole Winterhalter, U.S. Army Natick Soldier Research, Development and Engineering Ctr. (USA) . . . . [9470-21]

Formation of operation script by means of strategic foresight and international relations theories, Sefa Alioglu, Turkish Air War College (Turkey); Caner Nayki, Turkish Air War College (Turkey) . . . . [9470-22]

Interoperabilty, speaking the same language via tactical data link systems, Erdem Hekimhan, Savas Ozkaynak, Turkish Air War College (Turkey). . [9470-23]

Can unmanned aerial vehicles radically change the border security?, Abdullah Erkan, Turkish Air Force (Turkey) . . . . [9470-24]

Augmented reality: the applications of augmented reality in military area and military schools, Isa Haskologlu, Mehmet Sisman, Enes Erol, Turkish Military Academy (Turkey) . . . . [9470-37]

Performance and lifetime enhancements to legacy analog head-up displays systems, in military applications, through affordable digital upgrades, William P. Bleha, Paul Wisely, HOLOEYE Systems, Inc. (USA) . . . . [9470-38]

LCOS-based digital rifle scope display, William P. Bleha, Paul Wisely, HOLOEYE Systems, Inc. (USA). . . . . [9470-39]

CONFERENCE 9470B

Wednesday 22–22 April 2015 • Part of Proceedings of SPIE Vol. 9470

Head- and Helmet-Mounted Displays XX: Design and Applications

Conference Chairs: **Peter L. Marasco,** Air Force Research Lab. (USA); **Paul R. Havig,** Air Force Research Lab. (USA); **Michael P. Browne,** SA Photonics (USA); **James E. Melzer,** Rockwell Collins Optronics (USA)

Program Committee: **Randall E. Bailey,** NASA Langley Research Ctr. (USA); **Sion Jennings,** National Research Council Canada (Canada)

Tuesday 21 April

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Development of a helmet/helmet-display-unit alignment tool (HAT) for the Apache helmet and display unit, Thomas H. Harding, William E. McLean, Jonathan K. Statz, Clarence E. Rash, U.S. Army Aeromedical Research Lab. (USA) . . . . [9470-36]

Wednesday 22 April

SESSION 9 . . . . WED 8:30 AM TO 10:30 AM

Head and Helmet Mounted Displays: A Retrospective

Session Chair: **Michael P. Browne,** SA Photonics (USA)

A history of helmet mounted displays *(Invited Paper)*, Bobby D. Foote, Rockwell Collins, Inc. (USA); James E. Melzer, Rockwell Collins Optronics (USA) . . . . [9470-25]

The impact of human factors, crashworthiness and optical performance design requirements on helmet-mounted display development from the 1970s to the present *(Invited Paper)*, Thomas H. Harding, Clarence E. Rash, William E. McLean, John S. Martin, U.S. Army Aeromedical Research Lab. (USA) . . . . [9470-26]

In the blink of an eye; head mounted displays development within BAE Systems *(Invited Paper)*, Alexander A. Cameron, BAE Systems (United Kingdom) . . . . [9470-27]

A review of head-worn display research at NASA Langley Research Center *(Invited Paper)*, Jarvis J. Arthur III, Randall E. Bailey, Steven P. Williams, Lawrence J. Prinzel III, Kevin J. Shelton, Vincent E. Houston, NASA Langley Research Ctr. (USA) . . . . [9470-28]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:30 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 10 . . . . WED 1:00 PM TO 2:20 PM

Testing and Human Factors of HMDs

Session Chair: **James E. Melzer,** Rockwell Collins Optronics (USA)

Flight test of a head-worn display as an equivalent-HUD for terminal operations, Kevin J. Shelton, Jarvis J. Arthur III, Stephanie N. Nicholas, Randall E. Bailey, Steven P. Williams, Lawrence J. Prinzel III, NASA Langley Research Ctr. (USA). . . . . [9470-29]

Dynamic registration of an optical see-through HMD into a wide field-of-view rotorcraft flight simulation environment, Franz Viertler, Manfred Hajek, Technische Univ. München (Germany) . . . . [9470-30]

Visibility of monocular symbology in transparent head-mounted display applications, Marc Winterbottom, USAF School of Aerospace Medicine (USA); Robert Patterson, 711 HPW/RHX (USA); Byron Pierce, Certified Human Factors Professional (USA); James Gaska, Steven Hadley, USAFSAM (USA) . . [9470-31]

Visual fatigue induced by optical misalignment in binocular devices: application to night vision binocular devices, Maria Gavrilescu, Defence Science and Technology Organisation (Australia); Josephine Battista, Michael R. Ibbotson, National Vision Research Institute (Australia); Peter Gibbs, Defence Science and Technology Organisation (Australia). . . . . [9470-32]

SESSION 11. . . . . WED 2:20 PM TO 3:00 PM

Enabling Technologies

Enhancing head and helmet-mounted displays using a virtual pixel technology, Benjamin M. Kading, Jeremy Straub, Univ. of North Dakota (USA) . . . . [9470-33]

Polymer prisms for head hounted optical systems, Dave Schmidt, Howard Wong, Robert Benson, Rochester Precision Optics, LLC (USA) . . . . [9470-34]

SESSION 12 . . . . WED 3:30 PM TO 4:50 PM

Head and Helmet Mounted Displays and Display Technologies and Applications for Defense, Security, and Avionics

Joint Session with Conferences 9470A and 9470B

Session Chair: **Peter L. Marasco,** Air Force Research Lab. (USA)

Diver's full face mask head-up display using waveguide optical display technology, Dennis Gallagher, Richard Manley, Naval Surface Warfare Ctr. Panama City Div. (USA). . . . . [9470-1]

The impact of coloured symbology on cockpit eyes-out display effectiveness: a survey of key parameters, Maha Fares, Derek R. Jordan, BAE Systems (United Kingdom) . . . . [9470-35]

Augmented reality technology for heads-up, day/night situational awareness for the dismounted soldier, Eric Gans, Applied Research Associates, Inc. (USA) . . . . [9470-2]

Operational feedback on night vision with hyperstereoscopic HMD, Jean-Michel Francois, Thales Avionics S.A. (France); Daniel Maulet, Thales Angénieux S.A. (France); Joel Baudou, Thales Avionics S.A. (France) . . . . [9470-3]

CONFERENCE 9471

Tuesday 21–21 April 2015 • Proceedings of SPIE Vol. 9471

Degraded Visual Environments: Enhanced, Synthetic, and External Vision Solutions 2015

Conference Chairs: **Jeff J. Güell,** The Boeing Co. (USA); **Jack Sanders-Reed,** The Boeing Co. (USA)

Program Committee: **Jarvis J. Arthur III,** NASA Langley Research Ctr. (USA); **Cory Dixon,** Stratom, Inc. (USA); **Thomas R. Muensterer,** Cassidian (Germany); **Niklas Peinecke,** Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); **Christian Pschierer,** Jeppesen GmbH (Germany); **Carlo L. Tiana,** Rockwell Collins, Inc. (USA)

Tuesday 21 April

SESSION 1. . . . . .TUE 8:00 AM TO 10:00 AM

DVE Sensors I

Session Chairs: **Niklas Peinecke,** Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany); **Cory Dixon,** Stratom, Inc. (USA)

Subjective evaluation of a prototype night vision goggle, Gregory J. Hardy, The Boeing Co. (USA); Bobby D. Foote, Rockwell Collins, Inc. (USA) . . . [9471-1]

Fixed wing rests using polarized maintained OPAL lidar and non-polarized OPAL lidar, Philip M. Church, Evan Trickey, Xiaoying Cao, Neptec Technologies Corp. (Canada) . . . . [9471-2]

Passive, real-time millimeter wave imaging for degraded visual environment mitigation, Thomas E. Dillon, Christopher A. Schuetz, Richard D. Martin, Daniel G. Mackrides, Charles Harrity, Phase Sensitive Innovations, Inc. (USA); Dennis W. Prather, Univ. of Delaware (USA) . . . . [9471-3]

Testing of an improved passive millimeter wave imager for degraded visual environments applications, Colin D. Cameron, Rupert N. Anderton, QinetiQ Ltd. (United Kingdom); John N. Sanders-Reed, The Boeing Co. (USA); Dennis J. Yelton, Boeing-SVS, Inc. (USA); Gordon N. Sinclair, James G. Burnett, Philip J. Kent, QinetiQ Ltd. (United Kingdom); Jeff J. Güell, The Boeing Co. (USA) . . . . [9471-4]

LandSafe precision flight instrumentation system for rotorcraft operations in degraded environments, Pri Mamidipudi, Elizabeth Dakin, Optical Air Data Systems, LLC (USA) . . . . [9471-5]

A multi-beam radar altimeter: lessons learned with a MIMO solution, Ian D. Longstaff, The Univ. of Queensland (Australia) . . . . [9471-6]

SESSION 2 . . . . .TUE 10:30 AM TO 11:50 AM

DVE Sensors II

Session Chairs: **Christian Pschierer,** Jeppesen GmbH (Germany); **Carlo L. Tiana,** Rockwell Collins, Inc. (USA)

Three-dimensional landing zone joint capability technology demonstration results, James C. Savage, Air Force Research Lab. (USA) . . . . [9471-7]

An investigation in processing techniques for sidelobe suppression in millimeter wave DVE radars for imagery, Janeen Winne, U.S. Army Communications-Electronics Research Development and Engineering Command (USA); Antoinette Beasley, Lee Moyer, EOIR Technologies (USA) . . . . [9471-8]

Flight test results of ladar brownout look-through capability, Stephen Stelmash, Fairchild Controls Corp. (USA); Thomas R. Muensterer, Patrick Kramper, Christian Samuelis, Daniel Buehler, Matthias Wegner, Airbus Defence and Space (Germany); Sagar Sheth, Ferchau Engineering (Germany) . . . . [9471-9]

DVE flight test results of a sensor enhanced 3D conformal pilot support system, Thomas R. Muensterer, Philipp Voelschow, Bernhard Singer, Michael Strobel, Patrick Kramper, Airbus Defence and Space (Germany) . . . . . [9471-10]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . .TUE 1:20 PM TO 3:00 PM

Fusion, SVS, and Processing

Session Chairs: **Carlo L. Tiana,** Rockwell Collins, Inc. (USA); **Jarvis J. Arthur III,** NASA Langley Research Ctr. (USA)

Fusion of synthetic and live imagery in a two view domain, Larry Schaffer, GE Intelligent Platforms (USA). . . . . [9471-11]

Data fusion for a DVE solution, Noah Baird, Michael Crisafulli, ENSCO Avionics, Inc. (USA) . . . . [9471-12]

Is OpenSceneGraph an option for ESVS displays?, Niklas Peinecke, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany) . . . . [9471-13]

Combining IR imagery and 3D lidar-based symbology for a helicopter DVE support, Thomas R. Muensterer, Martin J. Kress, Airbus Defence and Space (Germany); Mark C. Lupton, Graham Passey, SELEX ES (United Kingdom) . . . . [9471-14]

Seamless situational awareness, Howard W. Wiebold, Honeywell (USA) . . . . [9471-15]

SESSION 4 . . . . TUE 3:30 PM TO 4:50 PM

Man-Machine Interface

Session Chairs: **Jarvis J. Arthur III,** NASA Langley Research Ctr. (USA); **Thomas R. Muensterer,** Cassidian (Germany)

Introduction of a 3D perspective view in the Navigation Display: featuring pilot's mental model, Lars Ebrecht, Sven Schmerwitz, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany) . . . . [9471-16]

Drift indication for helicopter approach and landing, Sven Schmerwitz, Patrizia M. Knabl, Thomas Lueken, Hans-Ullrich Doehler, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany) . . . . [9471-17]

Virtual aircraft-fixed cockpit instruments, Hans-Ullrich Doehler, Johannes M. Ernst, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany) . . . . [9471-18]

HMI aspects of the usage of ladar 3D data in pilot DVE support systems, Thomas R. Muensterer, Philipp Voelschow, Bernhard Singer, Michael Strobel, Patrick Kramper, Airbus Defence and Space (Germany) . . . . [9471-19]

SESSION 5 . . . . TUE 4:50 PM TO 5:50 PM

Compensation Techniques

Session Chairs: **Thomas R. Muensterer,** Cassidian (Germany); **Niklas Peinecke,** Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

Sensor modeling for precision ship-relative navigation in degraded visual environment conditions, Marcel Bergerman, Sanjiv Singh, Gary W. Sherwin, Regis M. Hoffman, Samuel Nalbone, Near Earth Autonomy, Inc. (USA); Lyle Chamberlain, Near Earth Autonomy, Inc. (USA) . . . . [9471-20]

Real-time correction of surveillance video for atmospheric distortion using FPGA-based processing, Steve C. J. Parker, RFEL Ltd. (United Kingdom) . . . . [9471-21]

Mathematical principles of settings for extremely high resolution in multi beams systems, Evgeni N. Terentiev, Lomonosov Moscow State Univ. (Russian Federation) . . . . [9471-22]

CONFERENCE 9472

Tuesday–Thursday 21–23 April 2015 • Proceedings of SPIE Vol. 9472

Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XXI

Conference Chairs: **Miguel Velez-Reyes,** The Univ. of Texas at El Paso (USA); **Fred A. Kruse,** Naval Postgraduate School (USA)

Program Committee: **Eustace L. Dereniak,** College of Optical Sciences, The Univ. of Arizona (USA); **Michael T. Eismann,** Air Force Research Lab. (USA); **Glenn E. Healey,** Univ. of California, Irvine (USA); **Jacqueline J. Le Moigne,** NASA Goddard Space Flight Ctr. (USA); **David W. Messinger,** Rochester Institute of Technology (USA); **Dalton S. Rosario,** U.S. Army Research Lab. (USA); **Alan P. Schaum,** U.S. Naval Research Lab. (USA); **James Theiler,** Los Alamos National Lab. (USA); **Grady Tuell,** Georgia Tech Research Institute (USA)

Tuesday 21 April

SESSION 1. . . . . TUE 8:30 AM TO 10:30 AM

Spectral Detection, Identification, and Quantification

Session Chair: **Miguel Velez-Reyes,** The Univ. of Texas at El Paso (USA); **Fred A. Kruse,** Naval Postgraduate School (USA)

Chemical agent resistant coating (CARC) detection using hyperspectral imager (HSI), Hai-Wen Chen, Michael McGurr, Mark Brickhouse, Booz Allen Hamilton Inc. (USA) . . . . [9472-1]

Metrics for the comparative evaluation of chemical plume identification algorithms, Eric Truslow, Northeastern Univ. (USA); Steven E. Golowich, Dimitris G. Manolakis, MIT Lincoln Lab. (USA); Vinay K. Ingle, Northeastern Univ. (USA) . . . . [9472-2]

Pattern recognition in hyperspectral persistent imaging, Dalton S. Rosario, U.S. Army Research Lab. (USA); Joao M. Romano, U.S. Army Armament Research, Development and Engineering Ctr. (USA); Christoph C. Borel-Donohue, Air Force Institute of Technology (USA) . . . . [9472-3]

Imaging white blood cells using a snapshot hyperspectral imaging system, Christopher J. Robison, Christopher J. Kolanko, Thirimachos Bourlai, Jeremy M. Dawson, West Virginia Univ. (USA) . . . . [9472-4]

Burn injury diagnostic imaging device's accuracy improved by outlier detection and removal, Weizhi Li, Weirong Mo, Xu Zhang, Yang Lu, Eric W. Sellke, Wensheng Fan, J. Michael DiMaio, Jeffery E. Thatcher, Spectral MD, Inc. (USA) . . . . [9472-5]

Skin segmentation by active learning for human detection in hyperspectral images, Ion Marques, Manuel Graña, Univ. del País Vasco (Spain); Stephanie M. Sanchez, Mohammed Q. Alkhatib, Miguel Velez-Reyes, The Univ. of Texas at El Paso (USA) . . . . [9472-6]

SESSION 2 . . . . TUE 11:00 AM TO 12:00 PM

Spectral Data Compression and Dimensionality Reduction

Session Chair: **Dalton S. Rosario,** U.S. Army Research Lab. (USA)

Multi-pass encoding of hyperspectral imagery with spectral quality control, Steven R. Wasson, William Walker, Applied Technology Associates (USA) . . . . [9472-7]

SLIC superpixels for efficient graph-based dimensionality reduction of hyperspectral imagery, Xuewen Zhang, Selene E. Chew, Zhenlin Xu, Nathan D. Cahill, Rochester Institute of Technology (USA) . . . . [9472-8]

A concept for hyperspectral imaging with compressive sampling and dictionary recovery, Robert R. Muise, David Twede, Lockheed Martin Missiles and Fire Control (USA). . . . . [9472-9]

Lunch/Exhibition Break . . . . Tue 12:00 pm to 1:30 pm

SESSION 3 . . . . TUE 1:30 PM TO 3:30 PM

Spectral Signature Modeling, Measurements, and Applications I

Session Chair: **Michael T. Eismann,** Air Force Research Lab. (USA)

Calculation of electronic-excited-state absorption spectra of water clusters using time-dependent density functional theory, Lulu Huang, Samuel G. Lambrakos, U.S. Naval Research Lab. (USA); Andrew Shabaev, George Mason Univ. (USA); Lou Massa, Hunter College (USA) . . . . [9472-10]

Comparison of microfacet BRDF model elements to diffraction BRDF model elements, Samuel D. Butler, Stephen E. Nauyoks, Michael A. Marciniak, Air Force Institute of Technology (USA) . . . . [9472-11]

Development of land surface reflectance models based on multiscale simulation, Adam A. Goodenough, Scott D. Brown, Rochester Institute of Technology (USA) . . . . [9472-12]

Advances in simulating radiance signatures for dynamic air/water interfaces, Adam A. Goodenough, Scott D. Brown, Aaron D. Gerace, Rochester Institute of Technology (USA) . . . . [9472-13]

Influence of density on hyperspectral BRDF signatures, Douglas S. Peck, Malachi J. Schultz, Charles M. Bachmann, Brittany Ambeau, Justin Harms, Rochester Institute of Technology (USA) . . . . [9472-14]

Development and comparison of data reconstruction methods for chromotomographic hyperspectral imagers, Michael R. Hawks, Air Force Institute of Technology (USA) and Oak Ridge Institute for Science & Education (USA); Alan L. Jennings, Air Force Institute of Technology (USA); Ryan Tervo, U.S. Air Force (USA) . . . . [9472-15]

SESSION 4 . . . . TUE 4:00 PM TO 5:40 PM

SHARE 2012 Analysis Results

Session Chair: **John Kerekes,** Rochester Institute of Technology (USA)

Target detection assessment of the SHARE 2010/2012 hyperspectral data collection campaign, Emmett J. Ientilucci, Rochester Institute of Technology (USA) . . . . [9472-16]

Comprehensive analysis results from the SHARE 2012 subpixel detection and unmixing experiments, Yihang Sun, John Kerekes, Rochester Institute of Technology (USA) . . . . [9472-17]

On the effects of spatial and spectral resolution on spatial-spectral target detection in SHARE 2012 and Bobcat 2013 hyperspectral imagery, Jason R. Kaufman, Exelis Space Computer Corp. (USA); Michael T. Eismann, Air Force Research Lab. (USA); Bradley M. Ratliff, Exelis Space Computer Corp. (USA); Mehmet Celenk, Ohio Univ. (USA) . . . . [9472-18]

Locating the shadow regions in LIDAR data: results on the SHARE 2012 Dataset, Seniha E. Yuksel, Hacettepe Univ. (Turkey); Mustafa Boyaci, ASELSAN Inc. (Turkey). . . . . [9472-19]

Effect of endmember clustering on proportion estimation: results on the Share 2012 Dataset, Seniha E. Yuksel, Hacettepe Univ. (Turkey); Erdinc Gunes, ASELSAN Inc. (Turkey) . . . . [9472-20]

Wednesday 22 April

SESSION 5 . . . . WED 8:30 AM TO 10:30 AM

Hyperspectral Target Detection

Session Chair: **David W. Messinger,**
Rochester Institute of Technology (USA)

Incorporating signal-dependent noise for hyperspectral target detection, Christopher J. Morman, Russell C. Hardie, Univ. of Dayton (USA); Joseph Meola, Air Force Research Lab. (USA) . . . . [9472-21]

Robust chemical and chemical-resistant material detection using hyperspectral imager, Hai-Wen Chen, Michael McGurr, Mark Brickhouse, Booz Allen Hamilton Inc. (USA). . . . . [9472-22]

An adaptive locally linear embedding manifold learning approach for hyperspectral target detection, Amanda K. Ziemann, David W. Messinger, Rochester Institute of Technology (USA) . . . . [9472-23]

Peripheral ellipsoids for anomaly detection in remote sensing imagery, Guenchik J. Grosklos, James P. Theiler, Los Alamos National Lab. (USA) . . . . [9472-24]

Video rate multispectral imaging for camouflaged target detection and tracking, Samuel T. Henry, James C. Jafolla, Surface Optics Corp. (USA) . . . . [9472-25]

Evaluating backgrounds for subpixel target detection: when closer isn't better, Nofar Hasson, Shmual Asulin, Dan G. Blumberg, Stanley R. Rotman, Ben-Gurion Univ. of the Negev (Israel) . . . . [9472-26]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:30 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours..

SESSION 6 . . . . .WED 1:10 PM TO 3:10 PM

Novel Mathematically-Inspired Methods of Processing Hyperspectral Airborne and Satellite Imagery: Novel Mathematics Algorithms I

Session Chair: **Jacqueline J. Le Moigne,**
NASA Goddard Space Flight Ctr. (USA)

Spatial-spectral dimensionality reduction of hyperspectral imagery with partial knowledge of class labels, Nathan D. Cahill, Selene E. Chew, Paul S. Wenger, Rochester Institute of Technology (USA) . . . . [9472-27]

Applications of direction-sensitive sparse representations to hyperspectral image analysis, Julia Dobrosotskaya, Case Western Reserve Univ. (USA) . . . . [9472-28]

Transitioning from semi-supervised to unsupervised feature extraction using Schrödinger Eigenmaps, Timothy Doster, U.S. Naval Research Lab. (USA) . . . . [9472-29]

Detecting plumes in LWIR using nonnegative matrix factorization and graph-based method, Jing Qin, Andrea L. Bertozzi, Univ. of California, Los Angeles (USA); Thomas Laurent, Loyola Marymount Univ. (USA); Justin Sunu, Claremont Graduate Univ. (USA); Kevin Bui, Shuyi Wang, Univ. of California, Los Angeles (USA); Ricardo V. R. Tan, Jasmine Dahilig, Loyola Marymount Univ. (USA); Jared L. Rohe, Univ. of San Francisco (USA) . . . . [9472-30]

Modeling and mitigating noise in graph and manifold representations of hyperspectral imagery, Charles M. Bachmann, Can Jin, Rochester Institute of Technology (USA) . . . . [9472-31]

Algorithms for retrieving temperature and emissivity from hyperspectral data in complex environments, Christoph C. Borel-Donohue, Air Force Institute of Technology (USA); Dalton S. Rosario, U.S. Army Research Lab. (USA); Joao M. Romano, U.S. Army Armament Research, Development and Engineering Ctr. (USA). . . . . [9472-32]

SESSION 7 . . . . WED 3:40 PM TO 5:40 PM

Novel Mathematically-Inspired Methods of Processing Hyperspectral Airborne and Satellite Imagery: Novel Mathematics Algorithms II

Session Chair: **Wojciech Czaja,** Univ. of Maryland, College Park (USA)

Classification of multi-modality sensor data with limited labeled data, Melba M. Crawford, Purdue Univ. (USA); Saurabh Prasad, Univ. of Houston (USA); Hsiuhan Yang, Purdue Univ. (USA); Xiong Zhou, Univ. of Houston (USA); Zhou Zhang, Purdue Univ. (USA) . . . . [9472-33]

LWIR HSI target detection in the urban canyon, Amit Banerjee, Joshua B. Broadwater, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . [9472-34]

Self-organization, neighborhoods, and possibilistic classification, Paul D. Gader, Leila Kalantari, Ron Fick, Univ. of Florida (USA). . . . . . . [9472-35]

Schrodinger Eigenmaps for spectral target detection, Leidy P. Dorado-Munoz, David W. Messinger, Rochester Institute of Technology (USA) . [9472-36]

Functions of multiple instances for sub-pixel target characterization in hyperspectral imagery, Alina Zare, Changzhe Jiao, Univ. of Missouri-Columbia (USA) . . . . [9472-37]

Anisotropic representations for superresolution of hyperspectral data, James M. Murphy, Wojciech Czaja, Daniel Weinberg, Edward Bosch, Univ. of Maryland, College Park (USA). . . . . [9472-38]

Thursday 23 April

SESSION 8 . . . . .THU 8:30 AM TO 10:30 AM

Spectral Signature Modeling, Measurements, and Applications II

Session Chair: **Emmett J. Ientilucci,**
Rochester Institute of Technology (USA)

The development of a DIRSIG simulation environment to support instrument trade studies for the SOLARIS sensor, Aaron D. Gerace, Jie Yang, Rochester Institute of Technology (USA); Joel McCorkel, NASA Goddard Space Flight Ctr. (USA) . . . . [9472-39]

Empirical measurement and model validation of infrared spectra of contaminated surfaces, Sean Archer, Michael G. Gartley, John Kerekes, Rochester Institute of Technology (USA); Bogdon R. Cosofret, Jay P. Giblin, Physical Sciences Inc. (USA). . . . . [9472-40]

Spectral analysis of water samples using modulated resonance features for monitoring of public water resources, Samuel G. Lambrakos, U.S. Naval Research Lab. (USA); Constantine Yapijakis, The Cooper Union for the Advancement of Science and Art (USA); Daniel Aiken, U.S. Naval Research Lab. (USA); Andrew Shabaev, George Mason Univ. (USA); Scott A. Ramsey, Joseph E. Peak, U.S. Naval Research Lab. (USA). . . . . [9472-41]

An accelerated line-by-line option for MODTRAN combining on-the-fly generation of line center absorption within 0.1 cm-1 bins and pre-computed line tails, Alexander Berk, Patrick F. Conforti, Lawrence S. Bernstein, Prabhat K. Acharya, Chona S. Guiang, Raphael Panfili, Spectral Sciences, Inc. (USA) . . . . [9472-42]

A comparison of all atmospheric transmission software, Dylan Payne, John Schroeder, Ontar Corporation (USA). . . . . [9472-43]

Atmospheric correction of shortwave hyperspectral imagery using a fast, full-scattering 1D-VAR retrieval scheme, Jean-Claude Thelen, Stephan Havemann, Jonathan P. Taylor, Gerald J. Wong, Met Office (United Kingdom) . . . . [9472-44]

CONFERENCE 9472

SESSION 9 . . . . THU 11:00 AM TO 12:00 PM

Spectral Sensor Design, Development, and Characterization

Session Chair: **Grady Tuell,** Georgia Tech Research Institute (USA)

Imaging polarization heterodyned interferometry using savart plates, Bryan D. Maione, Michael W. Kudenov, North Carolina State Univ. (USA). . . . [9472-45]

Passive standoff superresolution imaging using spatial-spectral multiplexing, Ethan Woodard, Michael W. Kudenov, North Carolina State Univ. (USA) . . . . [9472-46]

Automated turbulence and jitters correction with a dual port imaging Fourier-transform spectrometer, Florent M. Prel, Louis M. Moreau, Stéphane M. Lantagne, Claude B. Roy, ABB Analytical Measurement (Canada) . . [9472-47]

Lunch/Exhibition Break . . . . Thu 12:00 pm to 1:30 pm

SESSION 10 . . . . .THU 1:30 PM TO 2:50 PM

Data Fusion and Multiple Modality Spectral Applications

Session Chairs: **James P. Theiler,** Los Alamos National Lab. (USA); **Miguel Velez-Reyes,** The Univ. of Texas at El Paso (USA)

Integrated visible to near-infrared, shortwave infrared, and longwave infrared spectral analysis for surface composition mapping near Mountain Pass, California, Meryl L. McDowell, Scitor Corp. (USA) and Naval Postgraduate School (USA); Fred A. Kruse, Naval Postgraduate School (USA) . . . . [9472-54]

Exploration of integrated visible to near-, shortwave-, and longwave-infrared (full range) hyperspectral data analysis, Shelli R. Cone, Scitor Corp. (USA) and Naval Postgraduate School (USA); Fred A. Kruse, Naval Postgraduate School (USA); Meryl L. McDowell, Naval Postgraduate School (USA) and Scitor Corp. (USA) . . . . [9472-55]

Analysis of multispectral and hyperspectral longwave infrared (LWIR) data for geologic mapping, Fred A. Kruse, Naval Postgraduate School (USA); Meryl L. McDowell, Naval Postgraduate School (USA) and Scitor Corp. (USA)[9472-56]

Comparative analysis of airborne visible/infrared imaging spectrometer (AVIRIS) and hyperspectral thermal emission spectrometer (HyTES) longwave infrared (LWIR) hyperspectral data for geologic mapping, Fred A. Kruse, Naval Postgraduate School (USA) . . . . [9472-57]

SESSION 11 . . . . THU 3:20 PM TO 5:20 PM

Multispectral Applications

Session Chair: **Fred A. Kruse,** Naval Postgraduate School (USA)

Symmetrized regression for multispectral background estimation, James P. Theiler, Brendt E. Wohlberg, Los Alamos National Lab. (USA) . . . . [9472-48]

A comparison of directed search and in scene search target detection in Worldview-2 datasets, Stanley I. Grossman, National Geospatial-Intelligence Agency (USA) . . . . [9472-49]

Evaluation techniques and metrics for assessment of Pan+MSI fusion (Pansharpening), Ryan A. Mercovich, Vencore, Inc. (USA) . . . . [9472-50]

Snapshot imaging Fraunhofer line discriminator for detection of plant fluorescence, Subharup Gupta Roy, Michael W. Kudenov, North Carolina State Univ. (USA) . . . . [9472-51]

Assessing the impact of sub-pixel vegetation structure on imaging spectroscopy via simulation, Wei Yao, Jan A. N. van Aardt, Paul Romanczyk, David Kelbe, Martin van Leeuwen, Rochester Institute of Technology (USA) . . . . [9472-52]

Hyperspectral image-based methods for spectral biodiversity, Juan Carlos Santos Ferrer, David M. González Chévere, Univ. de Puerto Rico Mayagüez (USA); Ollantay Medina, Univ. of Puerto Rico (USA); Jesus Danilo Chinea, Vidya B. Manian, Univ. de Puerto Rico Mayagüez (USA) . . . . [9472-53]

INTERACTIVE POSTER SESSION
THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Cooperative spectral and spatial feature fusion for camouflaged target detection, Sungho Kim, Yeungnam Univ. (Korea, Republic of) . . . . [9472-58]

On the response function separability of push-broom hyperspectral imaging systems, Jurij Jemec, Univ. of Ljubljana (Slovenia); Franjo Pernuš, Boštjan Likar, Univ. of Ljubljana (Slovenia), Sensum d.o.o. (Slovenia); Miran Bürmen, Univ. of Ljubljana (Slovenia) . . . . [9472-59]

Evaluation of rainfall and NDVI anomalies using distributed lag models, Worku Zewdie Gebrehiwot, Elmar Csaplovics, Technische Univ. Dresden (Germany) . . . . [9472-60]

Skin detection in hyperspectral imagery, Stephanie M. Sanchez, Miguel Velez-Reyes, The Univ. of Texas at El Paso (USA) . . . . [9472-61]

Can we match ultraviolet face images against their visible counterparts?, Neeru Narang, Thirimachos Bourlai, West Virginia Univ. (USA) . . . . [9472-62]

CONFERENCE 9473

Monday–Tuesday 20–21 April 2015 • Proceedings of SPIE Vol. 9473

Geospatial Informatics, Fusion, and Motion Video Analytics V

Conference Chairs: **Matthew F. Pellechia,** Exelis, Inc. (USA); **Kannappan Palaniappan,** Univ. of Missouri-Columbia (USA); **Peter J. Doucette,** Integrity Applications, Inc. (USA); **Shiloh L. Dockstader,** Exelis, Inc. (USA); **Gunasekaran Seetharaman,** Air Force Research Lab. (USA)

Program Committee: **John A. Berger,** Toyon Research Corp. (USA); **Erik P. Blasch,** Air Force Research Lab. (Canada); **Bernard V. Brower,** Exelis, Inc. (USA); **Subhasis Chaudhuri,** Indian Institute of Technology Bombay (India); **Brian J. Daniel,** Exelis Inc. (USA); **Larry S. Davis,** Univ. of Maryland, College Park (USA); **Mark A. Duchaineau,** Google (USA); **Adel Hafiane,** Ecole Nationale Supérieure d'Ingénieurs (France); **Simon J. Julier,** Univ. College London (United Kingdom); **Haibin Ling,** Temple Univ. (USA); **Peter Paul,** Xerox Corp. (USA); **Robert B. Pless,** Washington Univ. in St. Louis (USA); **V. B. Surya Prasath,** Univ. of Missouri-Columbia (USA); **Kari A. Pulli,** NVIDIA Corp. (USA); **Ambasamudram Rajagopalan,** Indian Institute of Technology Madras (India); **Raghuveer M. Rao,** U.S. Army Research Lab. (USA); **John A. Richards,** Sandia National Labs. (USA); **Sartaj Sahni,** Univ. of Florida (USA); **Carl Salvaggio,** Rochester Institute of Technology (USA); **Stefano Soatto,** Univ. of California, Los Angeles (USA); **Suresh Subramanian,** Lockheed Martin Missiles and Fire Control (USA); **Bruce Swett,** EOIR Technologies (USA); **George R. Thoma,** National Library of Medicine (USA); **Darrell L. Young,** Raytheon Intelligence & Information Systems (USA); **Karmon M. Vongsy,** Air Force Research Lab. (USA); **V. B. Surya Prasath,** Univ. of Missouri-Columbia (USA)

Monday 20 April

INTRODUCTORY REMARKS. . . . . 1:40 PM TO 1:50 PM

Session Chair: **Matthew F. Pellechia,** Exelis Geospatial Systems (USA)

SESSION 1. . . . . .MON 1:50 PM TO 4:40 PM

Motion Video Analytics

Session Chair: **Gunasekaran Seetharaman,** Air Force Research Lab. (USA)

Streaming analysis of track data from video, Jiangqin Sun, David W. Messinger, Rochester Institute of Technology (USA) . . . . [9473-1]

Illumination robust change detection with CMOS imaging sensors, Vijay Rengarajan, Sheetal B. Gupta, Ambasamudram N. Rajagopalan, Indian Institute of Technology Madras (India); Gunasekaran Seetharaman, Air Force Research Lab. (USA) . . . . [9473-2]

Cueing motion blur for registration of inclined planar scenes, Arun A. Nair, Indian Institute of Technology Madras (India); Purnachandra Rao Makkena, IIT Madras (India); Ambasamudram N. Rajagopalan, Indian Institute of Technology Madras (India); Gunasekaran Seetharaman, Air Force Research Lab. (USA) . . . . [9473-3]

Object and activity detection from aerial video, Stephen Se, Feng Shi, Xin Liu, Mohsen Ghazel, MacDonald, Dettwiler and Associates Ltd. (Canada) . . . . [9473-4]

Application of VNIIRS for target tracking, Erik Blasch, Air Force Research Lab. (USA) . . . . [9473-5]

AESOP: adaptive event detection software using programming by example, Ashwin Thangali, Neal Checka, Harsha Prasad, Sai Kethamakka, Vecna Technologies, Inc. (USA) . . . . [9473-6]

Textured object video segmentation using temporal coherency, V. B. Surya Prasath, Rengarajan Pelapur, Raphael Viguier, Kannappan Palaniappan, Univ. of Missouri-Columbia (USA); Gunasekaran Seetharaman, Air Force Research Lab. (USA) . . . . [9473-7]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 2 . . . . .TUE 8:00 AM TO 10:00 AM

Geo-registration and Uncertainty Handling in Geospatial Data

Session Chair: **Shiloh L. Dockstader,** Exelis Geospatial Systems (USA)

Pedestrian dead reckoning using a novel sensor module that interfaces with modern smart devices, Gregory F. S. Hewitt, Phil J. Stimac, Mark J. McKenna, Matt Fordham, Richard Demar, Applied Research Associates, Inc. (USA) . . . . [9473-8]

Information fusion performance evaluation for motion imagery data, Soundararajan Ezekiel, Indiana Univ. of Pennsylvania (USA) . . . . [9473-9]

Video rate 3D registration of airborne video, David Bottisti, Lockheed Martin Missiles and Fire Control (USA); Suresh Subramaniam, The George Washington Univ. (USA) . . . . [9473-10]

Incorporating structure from motion uncertainty into image-based pose estimation, Ben Ludington, Andrew P. Brown, Michael Sheffler, Toyon Research Corp. (USA) . . . . [9473-11]

Full motion video geopositioning algorithm integrated test bed, John T. Dolloff, Bryant M. Hottel, Peter J. Doucette, Aaron Braun, Henry J. Theiss, Adam Gurson, Integrity Applications, Inc. (USA). . . . . [9473-12]

Geostatistical modeling of uncertainty, simulation, and proposed applications in GIScience, Peter J. Doucette, John T. Dolloff, Integrity Applications, Inc. (USA). . . . . [9473-13]

SESSION 3 . . . . .TUE 10:30 AM TO 11:50 AM

Enabling Architectures for Multi-Dimensional/Multisensing GIS

Session Chair: **Peter J. Doucette,** Integrity Applications, Inc. (USA)

GeoMesa: a distributed architecture for multi-source spatio-temporal fusion, Anthony Fox, Commonwealth Computer Research, Inc. (USA). [9473-14]

Addressing fundamental architectural challenges of an activity based intelligence and advanced analytics (ABIAA) system, Matthew F. Pellechia, Kevin C. Yager, Thomas A. Albert, Bernard V. Brower, Shiloh L. Dockstader, Exelis Inc. (USA) . . . . [9473-15]

Technologies for on-the-move standoff explosive hazard detection, Sanjeev Agarwal, Ronald R. Rupp, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Bruce Swett, Chris Burnett, EOIR Technologies (USA) . . . . [9473-16]

Semantically enabled wide-area image search, May V. Casterline, Kolia Sadeghi, Timothy Emerick, Commonwealth Computer Research, Inc. (USA) . . . . [9473-17]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

PANEL DISCUSSION. . . . . 1:20 PM TO 3:00 PM

Anticipative Computing for Autonomous Sensing and Analytics: What is over the horizon?

Moderator: **Kannappan Palaniappan**, Univ. of Missouri-Columbus (USA)

SESSION 4 . . . . TUE 3:30 PM TO 5:10 PM

Geoinformatics Processing Exploitation and Visualization

Session Chair: **Matthew F. Pellechia,** Exelis Geospatial Systems (USA)

Effects of camera location on the reconstruction of 3D flare trajectory with two cameras, Seçkin Özsaraç, Muhammed Ye?ilkaya, TÜBİTAK BİLGEM İLTAREN (Turkey) . . . . [9473-18]

Learning based roof style classification in 2D satellite images from Illinois Institute of Technology, Andi Zang, Xi Zhang, Gady Agam, Illinois Institute of Technology (USA); Xin Chen, Nokia Here.com (USA) and Illinois Institute of Technology (USA) . . . . [9473-19]

Context exploitation in intelligence, surveillance, and reconnaissance for detection and tracking algorithms, Jonathan D. Tucker, Lockheed Martin Corp. (USA); Robert Stanfill, Lockheed Martin Missiles and Fire Control (USA) . . . . [9473-20]

Mosaicing with Poisson blending regularization for wide area motion imagery, V. B. Surya Prasath, Raphael Viguier, Kannappan Palaniappan, Univ. of Missouri-Columbia (USA); Gunasekaran Seetharaman, Air Force Research Lab. (USA) . . . . [9473-21]

Real-time automated detection, tracking, classification, and geolocation of dismounts using EO and IR FMV, Justin Muncaster, Toyon Research Corp. (USA) . . . . [9473-22]

SEE PROFESSIONAL DEVELOPMENT COURSES
pages 145–214

CONFERENCE 9474

Monday–Wednesday 20–22 April 2015 • Proceedings of SPIE Vol. 9474

Signal Processing, Sensor/Information Fusion, and Target Recognition XXIV

Conference Chair: **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA)

Conference Co-Chairs: **Erik P. Blasch,** Air Force Research Lab. (USA); **Kenneth Hintz,** George Mason Univ. (USA); **Thia Kirubarajan,** McMaster Univ. (Canada); **Ronald P. S. Mahler,** Consultant (USA)

Program Committee: **Mark G. Alford,** Air Force Research Lab. (USA); **Bhashyam Balaji,** Defence Research and Development Canada (Canada); **William D. Blair,** Georgia Tech Research Institute (USA); **Mark J. Carlotto,** General Dynamics Advanced Information Systems (USA); **Alex L. Chan,** U.S. Army Research Lab. (USA); **Kuo-Chu Chang,** George Mason Univ. (USA); **Chee-Yee Chong,** Independent Consultant (USA); **Marvin N. Cohen,** Georgia Tech Research Institute (USA); **Frederick E. Daum,** Raytheon Co. (USA); **Jean Dezert,** The French Aerospace Lab. (France); **Mohammad Farooq,** AA Scientific Consultants Inc (Canada); **Laurie H. Fenstermacher,** Air Force Research Lab. (USA); **Charles W. Glover,** Oak Ridge National Lab. (USA); **I. R. Goodman,** Consultant (USA); **Lynne L. Grewe,** California State Univ., East Bay (USA); **Michael L. Hinman,** Air Force Research Lab. (USA); **Jon S. Jones,** Air Force Research Lab. (USA); **Georgiy M. Levchuk,** Aptima, Inc. (USA); **Martin E. Liggins II,** Consultant (USA); **James Llinas,** Univ. at Buffalo (USA); **Raj P. Malhotra,** Air Force Research Lab. (USA); **Alastair D. McAulay,** Lehigh Univ. (USA); **Raman K. Mehra,** Scientific Systems Co., Inc. (USA); **Harley R. Myler,** Lamar Univ. (USA); **David Nicholson,** BAE Systems (United Kingdom); **Les Novak,** Scientific Systems Co., Inc. (USA); **John J. Salerno Jr.,** Air Force Research Lab. (USA); **Andrew G. Tescher,** AGT Associates (USA); **Stelios C. A. Thomopoulos,** National Ctr. for Scientific Research Demokritos (Greece); **Wiley E. Thompson,** New Mexico State Univ. (USA); **Shanchieh Jay Yang,** Rochester Institute of Technology (USA)

Monday 20 April

SESSION 1. . . . . .MON 8:30 AM TO 10:10 AM

Multisensor Fusion, Multitarget Tracking, and Resource Management I

Session Chairs: **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Thiagalingam Kirubarajan,** McMaster Univ. (Canada); **Kenneth Hintz,** George Mason Univ. (USA)

Comparison of the performance of some multiple target tracking algorithms with experimental airborne radar data, Bhashyam Balaji, Defence Research and Development Canada (Canada); Kai Wang, MacDonald, Dettwiler and Associates Ltd. (Canada); Anthony Damini, Defence Research and Development Canada (Canada) . . . . [9474-1]

Aspects of detection and tracking of surface targets from an airborne EO/IR sensor, Bhashyam Balaji, Zahir Daya, Defence Research and Development Canada (Canada) . . . . [9474-2]

Computationally efficient angles-only tracking with particle flow filters, Russell Costa, Thomas A. Wettergren, Naval Undersea Warfare Ctr. (USA) . . . . [9474-3]

Multisensor fusion for 3D target tracking using track-before-detect particle filter, Nima Moshtagh, Paul M. Romberg, Moses W. Chan, Lockheed Martin Space Systems Co. (USA). . . . . [9474-4]

Target visibility for multiple maneuvering target tracking, Madeleine G. Sabordo, Elias Aboutanios, The Univ. of New South Wales (Australia) . . [9474-5]

SESSION 2 . . . . .MON 10:40 AM TO 12:20 PM

Multisensor Fusion, Multitarget Tracking, and Resource Management II

Session Chairs: **Thiagalingam Kirubarajan,** McMaster Univ. (Canada); **Kenneth Hintz,** George Mason Univ. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA)

Robust approach for space-based sensor bias estimation in the presence of data association uncertainty, Djedjiga Belfadel, Richard Osborne, Yaakov Bar-Shalom, Univ. of Connecticut (USA) . . . . [9474-6]

Square-root formulation of the SVSF with target tracking applications, Stephen A. Gadsden, Univ. of Maryland, Baltimore County (USA). . . . . . [9474-7]

Minimum-variance smoother based on the SVSF estimation strategy, Stephen A. Gadsden, Univ. of Maryland, Baltimore County (USA); Thia Kirubarajan, McMaster Univ. (Canada) . . . . [9474-8]

Orchestrated management of heterogeneous sensors incorporating feedback from intelligence assets, Yugandhar Sarkale, Edwin K. P. Chong, Colorado State Univ. (USA). . . . . [9474-9]

Probabilistic track-to-track association for attribute data fusion, Tim Zajic, Raytheon Co. (USA) . . . . [9474-10]

Lunch Break . . . . .Mon 12:20 pm to 1:15 pm

DEFENSE + SECURITY

PANEL DISCUSSION . . . . .1:15 PM TO 4:45 PM

Issues and Challenges of the Applications of Context to Enhance Information Fusion

Session Chair: **Alex L. Chan,** U.S. Army Research Lab. (USA)

Panel Organizers: **Erik Blasch**, Air Force Research Lab. (USA); **Ivan Kadar**, Interlink Systems Sciences, Inc, (USA)

Panel Moderators: **Ivan Kadar,** Interlink Sciences Systems, Inc. (USA); **Chee-Yee Chong,** Independent Consultant (USA)

Panel Members: **Erik Blasch,** Air Force Research Lab. (USA); **Alex L. Chan,** U.S. Army Research Lab. (USA); **Chee-Yee Chong,** Independent Consultant (USA); **Laurie H. Fenstermacher**, Air Force Research Lab. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Ronald P. S. Mahler,** Consultant (USA); **Alan N. Steinberg,** Independent Consultant (USA); **Paul Tandy,** Defense Threat Reduction Agency (USA); **Shancheih Jay Yang,** Rochester Institute of Technology (USA)

For a given application contextual information represents prior domain knowledge about the setting of the scenario/process to commence. The contextual knowledge can be acquired from prior (historical) experience, provided by external sources (e.g., user), learned from process experience, e.g., context awareness, prediction and search; and can be updated/corrected if changes are detected, e.g., by machine learning.

Context is present in all aspects of processing and interpreting information, situation, data, text, imagery, target tracking/identification, web-analytics, and intelligence systems outputs, that is, in all aspects/levels of information fusion (IF). Context is a multi-faceted entity, and can represent a setting for the assessment/interpretation of an event, scene, presence, situation, condition, constraint, influence, and many other entities clearly scenario/application dependent. There is context within context. Furthermore, context is not a static entity and can change over time (e.g., operating conditions, environment, geography, weather, seasons, roads, traffic, attitudes, behavior, preferences) affecting the performance of a given application if not managed and taken into account. Therefore, it is important to incorporate contextual information at the outset in all IF levels and associated systems designs in order to enhance the performance of the overall IF system and the on-going application.

For example in tracking application one can describe at least five contextual categories: (1) domain knowledge from a user to aid the information fusion process through selection, cueing, and analysis, (2) environment-to-hardware processing for sensor management, (3) known distribution of entities for situation/threat assessment, (4) historical traffic behavior for situation awareness patterns of life (POL), and (5) road information for target tracking and identification. Appropriate characterization and representation of contextual information is needed for future high-level information fusion systems design to take advantage of the large data content available for a priori knowledge target tracking algorithm construction, implementation, and application.

The objective of this panel is to bring to the attention of the fusion community the importance of the application of contextual knowledge to enhance IF, highlighting issues, illustrating potential approaches and addressing challenges. A number of invited experts will discuss challenges of the fusion process and research to address these challenges. The panelists will illustrate parts of the above mentioned areas over different applications and address all levels of information fusion. Conceptual and real-world related examples associated with the use of context to enhance IF will be used by the panel to highlight impending issues and challenges.

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 3 . . . . .TUE 8:00 AM TO 11:10 AM

Information Fusion Methodologies and Applications I

Session Chair: **Ronald P.S. Mahler,** Consultant (USA)

CPHD filters with unknown quadratic clutter generators, Ronald P. S. Mahler, Consultant. (USA) . . . . [9474-11]

On multitarget pairwise-Markov models, Ronald P. S. Mahler, Consultant (USA) . . . . [9474-12]

Distributed fusion of multitarget densities and consensus PHD filters, Giorgio Battistelli, Luigi Chisci, Claudio Fantacci, Univ. degli Studi di Firenze (Italy); Alfonso Farina, Antonio Graziano, SELEX ES S.p.A. (Italy); Ronald P. S. Mahler, Consultant (USA) . . . . [9474-13]

A distributed general multisensor cardinalized probability hypothesis density (CPHD) filter for sensor networks, Mark Coates, Santosh Nannuru, Michael Rabbat, Syamantak Datta Gupta, McGill Univ. (Canada) . . . . . [9474-14]

Integrate knowledge acquisition with target recognition through closed-loop ATR, Ssu-Hsin Yu, Pat McLaughlin, Aleksandar Zatezalo, Scientific Systems Co., Inc. (USA) . . . . [9474-15]

Multi-threat orbital evasion, Aleksandar Zatezalo, Scientific Systems Co., Inc. (USA); Dusan M. Stipanovic, Univ. of Illinois at Urbana-Champaign (USA); Ssu-Hsin Yu, Raman K Mehra, Scientific Systems Co., Inc. (USA) . . . . [9474-16]

Distributed estimation and control for unmanned systems, Aleksandar Zatezalo, Scientific Systems Co., Inc. (USA); Dusan M. Stipanovic, Univ. of Illinois at Urbana-Champaign (USA); Ssu-Hsin Yu, Raman K. Mehra, Scientific Systems Co., Inc. (USA) . . . . [9474-17]

Stochastic geometry for space situational awareness, Ba-Ngu B. Vo, Ba-Tuong Vo, Curtin Univ. (Australia) . . . . [9474-18]

SESSION 4 . . . . TUE 11:10 AM TO 11:50 AM

Information Fusion Methodologies and Applications II

Session Chairs: **Chee-Yee Chong,** Independent Consultant (USA); **Michael L. Hinman,** Air Force Research Lab. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Kenneth Hintz,** George Mason Univ. (USA)

Proof that particle flow corresponds to Bayes' rule: necessary and sufficient conditions, Frederick E. Daum, Raytheon Co. (USA) . . . . . . [9474-19]

Eight new particle flows for nonlinear filters, Bayesian decisions and transport, Frederick E. Daum, Jim Huang, Raytheon Co. (USA) . . . . . . [9474-20]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 5 . . . . .TUE 1:20 PM TO 3:00 PM

Information Fusion Methodologies and Applications III

Session Chairs: **Chee-Yee Chong,** Independent Consultant (USA); **Michael L. Hinman,** Air Force Research Lab. (USA); **Ivan Kadar,** Interlink Systems Sciences, Inc. (USA); **Kenneth Hintz,** George Mason Univ. (USA)

Feynman path integral and Monte Carlo methods for nonlinear filtering, Bhashyam Balaji, Defence Research and Development Canada (Canada) . . . . [9474-21]

Feature-aided multiple hypothesis tracking using topological and statistical behavior classifiers, David M. Rouse, Johns Hopkins Univ Applied Physics Lab. (USA); Adam S. Watkins, Jonathan T. DeSena, Jesse C. Clarke, David W. Porter, Jeffrey Gilbert, Johns Hopkins Univ. Applied Physics Lab., LLC (USA); Paul Bendich, Nathaniel Strawn, Elizabeth Munch, John Harer, Duke Univ. (USA); Peter Chin, Draper Lab. (USA); Andrew J. Newman, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . . [9474-22]

OCULUS Sea Track fusion service, Stylianos C. Panagiotou, Constantinos Rizogiannis, Stavros Katsoulis, Vassilis Lampropoulos, Sotirios Kanellopoulos, Stelios C. A. Thomopoulos, National Ctr. for Scientific Research Demokritos (Greece) . . . . [9474-23]

OCULUS Sea: a maritime surveillance platform, Sotirios Kanellopoulos, Stavros Katsoulis, Dionysis Motos, Vassilis Lampropoulos, Christos Margonis, Kostantinos Dimitros, Stelios C. A. Thomopoulos, National Ctr. for Scientific Research Demokritos (Greece) . . . . [9474-24]

A technique for sensors fusion with limited number of common measures, Carlo Quaranta, Giorgio Balzarotti, SELEX ES S.p.A. (Italy) . . . . [9474-25]

SESSION 6 . . . . TUE 3:30 PM TO 6:00 PM

Information Fusion Methodologies and Applications III

Session Chairs: **Michael L. Hinman,** Air Force Research Lab. (USA); **Kenneth Hintz,** George Mason Univ. (USA); **Erik Blasch,** Air Force Research Lab. (USA); **Chee-Yee Chong,** Independent Consultant (USA)

Grid occupancy estimation for autonomous vehicle perception based on belief functions and a proportional conflict redistribution rule of combination, Julien Moras, Jean Dezert, Benjamin Pannetier, ONERA (France) . . . . [9474-26]

Issues and challenges of information fusion in contested environments panel, Erik Blasch, Air Force Research Lab. (USA); Ivan Kadar, Interlink Systems Sciences, Inc. (USA); Chee-Yee Chong, Independent Consultant (USA); Eric K. Jones, Systems & Technology Research (USA); Laurie H. Fenstermacher, Air Force Research Lab. (USA); John D. Gorman, Defense Advanced Research Projects Agency (USA); Georgiy M. Levchuk, Aptima, Inc. (USA); Jorge E. Tierno, Barnstorm Research Corp. (USA) . . . . [9474-27]

Multi-intelligence critical rating assessment of fusion techniques (MiCRAFT), Erik Blasch, Air Force Research Lab. (USA) . . . . [9474-28]

Data fusion, association, and retrieval in open-source multimedia, Georgiy M. Levchuk, Aptima, Inc. (USA). . . . . [9474-29]

Optimal fusion rules for label fusion of classification systems, Jim Fitch, Mark E. Oxley, Christine M. Schubert Kabban, Air Force Institute of Technology (USA) . . . . [9474-30]

Weighted Kullback-Leibler average-based distributed filtering algorithm, Kelin Lu, Beihang Univ. (China); Kuochu C. Chang, George Mason Univ. (USA); Rui Zhou, Beihang Univ. (China) . . . . [9474-31]

Categorification of the Dempster Shafer theory, Joseph J. Peri, Johns Hopkins Univ. Applied Physics Lab., LLC (USA). . . . . [9474-32]

INTERACTIVE POSTER SESSION
TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Obstacle detection for unmanned ground vehicle in outdoor environment, Tok Son Choe, Jin-Bae Park, Yonsei Univ. (Korea, Republic of); Sang Hyun Joo, Yong Woon Park, Agency for Defense Development (Korea, Republic of) . . . . [9474-52]

Fast HOG features extraction using circle filter for car detection in aerial images, Ang Su, Yueqiang Zhang, Qifeng Yu, Xiaohu Zhang, Yang Shang, Xiaochun Liu, National Univ. of Defense Technology (China) . . . . [9474-53]

Use of open space box: supporting tele-medicine in space through efficient data transmission, Atif F. Mohammad, Jeremy Straub, The Univ. of North Dakota (USA). . . . . [9474-54]

The challenges of implementing and testing two signal processing algorithms for high rep-rate coherent Doppler lidar for wind sensing, Sameh Abdelazim, Fairleigh Dickinson Univ. (USA); David Santoro, Mark F. Arend, Fred Moshary, Samir Ahmed, The City College of New York (USA) . . . . [9474-55]

On an efficiency and effective intelligent transportation system (ITS) safety and traffic efficiency applications with corresponding driver's behavior, Nnanna N. Ekedebe, Nicolas Dolphin, Towson Univ. (USA) . . . . [9474-56]

Magnetic dipole parameter estimation and tracking using extended Kalman filter, Bhashyam Balaji, Bradley J. Nelson, Defence Research and Development Canada (Canada). . . . . [9474-57]

Bearing and frequency estimation using Cardiod sensors, Bhashyam Balaji, Defence Research and Development Canada (Canada). . . . . [9474-58]

The cubature smooth variable structure filter application into a quad-copter, Mohammad Al-Shabi, Philadelphia Univ. (Jordan); Stephen A. Gadsden, Univ. of Maryland, Baltimore (USA). . . . . [9474-59]

Wednesday 22 April

SESSION 7 . . . . WED 8:00 AM TO 10:00 AM

Signal and Image Processing, and Information Fusion Applications I

Session Chairs: **Lynne L. Grewe,** California State Univ., East Bay (USA); **Mark J. Carlotto,** General Dynamics Advanced Information Systems (USA); **Mark G. Alford,** Air Force Research Lab. (USA)

Learning representations for improved target identification, scene classification, and information fusion, Arjuna Flenner, Jennifer Flenner, Naval Air Warfare Ctr. Weapons Div. (USA) . . . . [9474-33]

Effects of the experimental manipulation of Fourier components of naturalistic imagery on search performance and eye-tracking behavior, Alan R. Pinkus, Air Force Research Lab. (USA); James S. Garrett, Consortium Research Fellows Program (USA); Allan J. Pantle, Miami Univ. (USA) . . [9474-34]

Fast object detection for low powered ISR systems, Olegs Mise, GE Intelligent Platforms (USA); Lee D. Wren, GE Intelligent Platforms (United Kingdom) . . . . [9474-35]

An infrared-visible image fusion scheme based on NSCT and compressed sensing, Qiong Zhang, Xavier Maldague, Univ. Laval (Canada) . . . . . . [9474-36]

Model-based detection, segmentation, and classification of compact objects, Mark J. Carlotto, General Dynamics Advanced Information Systems (USA) . . . . [9474-37]

Change detection by extended image differencing applied to IR video, Günter Saur, Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung (Germany) . . . . [9474-38]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours

SESSION 8 . . . . WED 1:00 PM TO 3:00 PM

Signal and Image Processing, and Information Fusion Applications II

Session Chairs: **Mark J. Carlotto,** General Dynamics Advanced Information Systems (USA); **Lynne L. Grewe,** California State Univ., East Bay (USA); **Mark G. Alford,** Air Force Research Lab. (USA)

Search by photo methodology for signature properties assessment by human observers, Gorm K. Selj, Daniela H. Heinrich, Norwegian Defence Research Establishment (Norway) . . . . [9474-39]

Cross-modal face recognition using multi-matcher face scores, Yufeng Zheng, Alcorn State Univ. (USA); Erik Blasch, Air Force Research Lab. (USA) . . . . [9474-40]

Dimensionality analysis of facial signatures in visible and thermal spectra, Nathaniel Short, Booz Allen Hamilton Inc. (USA); Shuowen Hu, U.S. Army Research Lab. (USA); Prudhvi Gurram, MBO Partners (USA). . . . . [9474-41]

Unsupervised classification of airborne particulate materials from optical scattering patterns, Giovanni Franco Crosta, Univ. degli Studi di Milano-Bicocca (Italy); Yongle Pan, Gorden Videen, U.S. Army Research Lab. (USA) . . . . [9474-42]

Muzzle flash localisation for the dismounted soldier, William J. Kennedy Scott, QinetiQ Ltd. (United Kingdom) . . . . [9474-43]

The Locus analytical framework for indoor localization and tracking applications, Olga E. Segou, Stelios C. A. Thomopoulos, National Ctr. for Scientific Research Demokritos (Greece) . . . . [9474-44]

SESSION 9 . . . . WED 3:30 PM TO 5:50 PM

Signal and Image Processing, and Information Fusion Applications III

Session Chairs: **Mark G. Alford,** Air Force Research Lab. (USA); **Mark J. Carlotto,** General Dynamics Advanced Information Systems (USA); **Lynne L. Grewe,** California State Univ., East Bay (USA)

Occlusion, optimization, emergency response and partial falls in a senior collapse detection system, Lynne L. Grewe, Steven Magaña-Zook, California State Univ., East Bay (USA). . . . . [9474-45]

Design for a source-agile automatic direction finder (ADF), Harley R. Myler, Lamar Univ. (USA) . . . . [9474-46]

Range resolution improvement in passive bistatic radars using nested FM channels and least squares approach, Rasim A. Sevimli, Musa T. Arslan, Ahmet E. Cetin, Bilkent Univ. (Turkey). . . . . [9474-47]

Vehicle engine classification using vibrations measured by laser Doppler vibrometer on pre-planted nearby objects, Jie Wei, Chi-Him Liu, Zhigang Zhu, The City College of New York (USA); Karmon M. Vongsy, Olga Mendoza-Schrock, Air Force Research Lab. (USA) . . . . [9474-48]

Exploitation of vibrometry data, Karmon M. Vongsy, Air Force Research Lab. (USA); Ashley N. Smith, Wright State Univ. (USA). . . . . [9474-49]

Comparing and contrasting Bayesian and Dempster-Shafer models of multisensor information fusion, Buddy H. Jeun, John R. Younker, Sensor Fusion Technology, LLC (USA) . . . . [9474-50]

Infrared small target detection algorithm based on multiscale codebook model, Lei Liu, Yayun Zhou, Nanjing Univ. of Science and Technology (China) . . . . [9474-51]

CONFERENCE 9475

Thursday 23 April 2015 • Proceedings of SPIE Vol. 9475

Algorithms for Synthetic Aperture Radar Imagery XXII

Conference Chairs: **Edmund Zelnio,** Air Force Research Lab. (USA); **Frederick D. Garber,** Wright State Univ. (USA)

Program Committee: **David Blacknell,** Defence Science and Technology Lab. (United Kingdom); **Mujdat Cetin,** Sabanci Univ. (Turkey); **Gil J. Ettinger,** Systems & Technology Research (USA); **Charles V. Jakowatz Jr.,** Sandia National Labs. (USA); **Eric R. Keydel,** SAIC (USA); **Juan Li,** Univ. of Central Florida (USA); **Michael J. Minardi,** Air Force Research Lab. (USA); **Randolph L. Moses,** The Ohio State Univ. (USA); **Les Novak,** Scientific Systems Co., Inc. (USA); **Lee C. Potter,** The Ohio State Univ. (USA); **Brian Rigling,** Wright State Univ. (USA); **Timothy D. Ross,** Jacobs Technology (USA); **Gerard W. Titi,** BAE Systems (USA)

Thursday 23 April

CONFERENCE WELCOME . . . . 8:00 AM TO 8:10 AM

SESSION 1. . . . . THU 8:10 AM TO 9:30 AM

Advanced SAR Imaging and Moving Target Detection

Session Chair: **Jason T. Parker,** Air Force Research Lab. (USA)

Ultra-narrowband SAR imaging using low-rank matrix recovery techniques, Eric Mason, Birsen Yazici, Rensselaer Polytechnic Institute (USA); Uttam Majumder, Edmund G. Zelnio, Air Force Research Lab. (USA) . . . . [9475-1]

Analysis and sharpening of radar image reconstruction via debiasing the lasso, Il-Young Son, Birsen Yazici, Rensselaer Polytechnic Institute (USA); Edmund G. Zelnio, Uttam Majumder, Air Force Research Lab. (USA) . . . [9475-2]

Optimized data sample for SAR imaging with irregular coverage, Thorkild B. Hansen, Seknion, Inc. (USA); Ross W. Deming, Solid State Scientific Corp. (USA) . . . . [9475-3]

Gradient projection for interrupted SAR using the polar format algorithm, Ross W. Deming, Solid State Scientific Corp. (USA); Chad Knight, Space Dynamics Lab. (USA) and Utah State Univ. (USA) . . . . [9475-4]

Back projection based Bistttic SAR DCPA for moving target imaging, Kaan Duman, Birsen Yazici, Rensselaer Polytechnic Institute (USA). . . . . [9475-5]

Knowledge-aided GMTI in a Bayesian framework, Michael Riedl, Lee C. Potter, The Ohio State Univ. (USA) . . . . [9475-6]

ATI design considerations to maximize SAR and GMTI performance, Chad Knight, Space Dynamics Lab. (USA); Ross W. Deming, Solid State Scientific Corp. (USA) . . . . [9475-7]

Geolocation of moving targets in gotcha data using multimode processing, Unnikrishna Pillai, Polytechnic Institute of New York Univ. (USA); Ke Yong Li, C&P Technologies, Inc. (USA); Steven M. Scarborough, Air Force Research Lab. (USA) . . . . [9475-8]

SESSION 2 . . . . THU 9:30 AM TO 11:50 AM

Recognition, Detection, and Signature Analysis usin gSAR

Session Chair: **Christopher Paulson,** Air Force Research Lab. (USA)

A new polarimetric maximum-likelihood change estimator for two-pass SAR coherent change detection, David A. Yocky, Daniel E. Wahl, Charles V. Jakowatz Jr., Sandia National Labs. (USA). . . . . [9475-9]

SAR image statistics and adaptive signal processing for change detection, Viet T. Vu, Renato Machado, Mats I. Pettersson, Blekinge Institute of Technology (Sweden); Patrik Dammert, Hans Hellsten, Saab Electronic Defence Systems (Sweden). . . . . [9475-10]

Signature predictions of surface targets undergoing turning maneuvers in spotlight synthetic aperture radar imagery, David A. Garren, Naval Postgraduate School (USA). . . . . [9475-11]

Joint azimuth and elevation localization estimates in 3D synthetic aperture radar scenarios, Matthew P. Pepin, Sandia Staffing Alliance, LLC (USA) . . . . [9475-12]

Characterization of stationary and moving shadows in synthetic aperture radar imagery, John Miller, Edward Bishop, General Atomics Aeronautical Systems, Inc. (USA); Armin W. Doerry, Ann M. Raynal, Sandia National Labs. (USA) . . . . [9475-13]

Asymptotic modeling of synthetic aperture ladar sensor phenomenology, Robert Neuroth, Air Force Research Lab. (USA); Brian D. Rigling, Wright State Univ. (USA); Edmund G. Zelnio, Air Force Research Lab. (USA); Edward A. Watson, Univ. of Dayton Research Institute (USA); Vincent J. Velten, Todd V. Rovito, Air Force Research Lab. (USA) . . . . [9475-14]

Layover analysis in synthetic aperture radar images, Ling Wang, Nanjing Univ. of Aeronautics and Astronautics (China); Birsen Yazici, Rensselaer Polytechnic Institute (USA) . . . . [9475-15]

Deep convolutional neural networks for ATR from SAR imagery, David A. E. Morgan, BAE Systems (United Kingdom) . . . . [9475-16]

Mixture of factor analyzers models of appearance manifolds for resolved SAR targets, Tarek Abdelrahman, Emre Ertin, The Ohio State Univ. (USA) . . . . [9475-17]

Sensitivity to number of quantization levels on quantization based ATR algorithm, Matt S. Horvath, Brian D. Rigling, Wright State Univ. (USA). [9475-18]

Impact of phase of radar range profiles in target classification, Linda J. Moore, Air Force Research Lab. (USA) and Univ. of Dayton (USA); Brian D. Rigling, Wright State Univ. (USA); Robert P. Penno, Univ. of Dayton (USA) . . . . [9475-19]

Lunch/Exhibition Break . . . . Thu 12:00 pm to 1:50 pm

POSTER SESSION . . . . 1:50 PM TO 3:30 PM

DISCUSSION/WORKSHOP . . . . 4:00 PM TO 4:50 PM

CONFERENCE 9476

Monday–Thursday 20–23 April 2015 • Proceedings of SPIE Vol. 9476

Automatic Target Recognition XXV

Conference Chairs: **Firooz A. Sadjadi,** Lockheed Martin Advanced Technology Labs. (USA); **Abhijit Mahalanobis,** Lockheed Martin Missiles and Fire Control (USA)

Program Committee: **Mohammad S. Alam,** Univ. of South Alabama (USA); **Farid Amoozegar,** Jet Propulsion Lab. (USA); **Mahmood R. Azimi-Sadjadi,** Colorado State Univ. (USA); **David Casasent,** Carnegie Mellon Univ. (USA); **Leon Cohen,** Hunter College (USA); **Frederick D. Garber,** Wright State Univ. (USA); **Guillermo C. Gaunaurd,** Consultant (USA); **Izidor Gertner,** The City College of New York (USA); **Patti S. Gillespie,** U.S. Army Research Lab. (USA); **Riad I. Hammoud,** BAE Systems (USA); **Bahram Javidi,** Univ. of Connecticut (USA); **Ismail I. Jouny,** Lafayette College (USA); **Behzad Kamgar-Parsi,** U.S. Naval Research Lab. (USA); **Timothy J. Klausutis,** Air Force Research Lab. (USA); **Wolfgang Kober,** Data Fusion Corp. (USA); **Aaron D. Lanterman,** Georgia Institute of Technology (USA); **Randolph L. Moses,** The Ohio State Univ. (USA); **Robert R. Muise,** Lockheed Martin Missiles and Fire Control (USA); **Nasser M. Nasrabadi,** U.S. Army Research Lab. (USA); **Les Novak,** Scientific Systems Co., Inc. (USA); **Joseph A. O'Sullivan,** Washington Univ. in St. Louis (USA); **Mubarak Ali Shah,** Univ. of Central Florida (USA); **Andre U. Sokolnikov,** Visual Solutions and Applications (USA); **Alan J. Van Nevel,** Naval Air Warfare Ctr. Aircraft Div. (USA); **Bradley C. Wallet,** Automated Decisions LLC (USA); **Edmund Zelnio,** Air Force Research Lab. (USA)

Monday 20 April

SESSION 1. . . . . MON 8:30 AM TO 9:50 AM

New Methodologies in ATR I

Session Chair: **Firooz A. Sadjadi,** Lockheed Martin Corp. (USA)

Target classification strategies, Bruce J. Schachter, Northrop Grumman Electronic Systems (USA) . . . . [9476-1]

Mutual information for enhanced feature selection in visual tracking, Victor Stamatescu, Anthony Milton, Univ. of South Australia (Australia); Sebastien Wong, Defence Science and Technology Organisation (Australia); Ivan Lee, David Kearney, Univ. of South Australia (Australia). . . . . [9476-2]

The effect of contrast in camouflage patterns on detectability by human observers and CAMAELEON, Daniela H. Heinrich, Gorm K. Selj, Norwegian Defence Research Establishment (Norway) . . . . [9476-3]

Evaluation methodology for query-based scene understanding systems, Todd P. Huster, Jacobs Engineering Group Inc. (USA) and Air Force Research Lab. (USA); Timothy D. Ross, Jacobs Engineering Group Inc. (USA) and Air Force Research Lab. (USA); Jared L. Culbertson, Air Force Research Lab. (USA) . . . . [9476-4]

SESSION 2 . . . . MON 10:20 AM TO 11:50 AM

New Methodologies in ATR II

Session Chair: **Abhijit Mahalanobis,** Lockheed Martin Missiles and Fire Control (USA)

Ambiguities of instantaneous frequency, and complex signal representations through pole-zero manipulations *(Invited Paper)*, Patrick J. Loughlin, Univ. of Pittsburgh (USA). . . . . [9476-5]

A novel method for determining target detection thresholds, Stanley I. Grossman, National Geospatial-Intelligence Agency (USA) . . . . . . [9476-6]

Shape-based features for ship classification, Katie Rainey, Erin Spindle, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9476-7]

Sparsity-driven anomaly detection for ship detection and tracking in maritime video, Joshua D. Harguess, Scott Shafer, Pedro Forero, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9476-8]

Lunch/Exhibition Break . . . . Mon 11:50 am to 1:20 pm

SESSION 3 . . . . MON 1:20 PM TO 2:40 PM

New Methodologies in ATR III

Session Chair: **Izidor Gertner,** The City College of New York (USA)

Vessel classification in overhead satellite imagery using weighted "bag of visual words", Shibin Parameswaran, Katie Rainey, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9476-9]

Segmentation and tracking of electrokinetic particles in microscopic video, Qiang Le, Hampton Univ. (USA); Shizhi Qian, Old Dominion Univ. (USA) . . . . [9476-10]

Shape distance transform for morphological filtering and landing site selection, Bing C. Li, Lockheed Martin Systems Integration-Owego (USA) . . . . [9476-11]

An approach to automatic detection of suspicious individuals in a crowd, Stephen Lucci, Satabdi Mukherjee, Izidor Gertner, The City College of New York (USA) . . . . [9476-12]

SESSION 4 . . . . MON 3:20 PM TO 4:20 PM

Radar/SAR ATR

Session Chair: **Firooz A. Sadjadi,** Lockheed Martin Corp. (USA)

Empirical evaluation of standard tracking process models and proposed enhancements, Bhargav R. Avasarala, Northrop Grumman Corp. (USA); Ryan Turner, Steven Bottone, Northrop Grumman Corp. (USA); Clay J. Stanek, Northrop Grumman Corp. (USA) . . . . [9476-13]

Aided target recognition using hyperdimensional manifolds, Shih-Chi K. Chen, Robert Stanfill, Abhijit Mahalanobis, Lockheed Martin Missiles and Fire Control (USA). . . . . [9476-14]

Feature analysis and saliency characterization for SAR ATR of civilian vehicles, Aaron McCauley, Julie Ann Jackson, Brian Woolley, Michael Seal, Air Force Institute of Technology (USA) . . . . [9476-15]

DSS PLENARY PRESENTATION . . MON 5:00 PM TO 6:00 PM

Alan R. Shaffer
Principal Deputy Assistant Secretary of Defense Research and Engineering
Department of Defense

Tuesday 21 April

SESSION 5 . . . . TUE 8:00 AM TO 9:50 AM

Underwater/Acoustic/Sonar ATR

Enhanced target versus clutter discrimination using time-frequency (LTV) filters *(Invited Paper)*, Vikram T. Gomatam, Patrick J. Loughlin, Univ. of Pittsburgh (USA) . . . . [9476-16]

Stereo image segmentation with application in underwater fish detection and tracking, Madhuri Gundam, Dimitrios Charalampidis, George E. Ioup, Juliette W. Ioup, Univ. of New Orleans (USA); Charles H. Thompson, National Marine Fisheries Service (USA) . . . . [9476-17]

Types and classification of noises *(Invited Paper)*, Leon Cohen, Hunter College (USA) . . . . [9476-18]

Why the inverse scattering by topological sensitivity may work, Bojan Guzina, Fatemeh Pourahmadian, Univ. of Minnesota, Twin Cities (USA)[9476-19]

Knowledge-directed adaptive automated underwater sonar mine detection and classification, Firooz A. Sadjadi, Lockheed Martin Corp. (USA) . . [9476-20]

SESSION 6 . . . . .TUE 10:30 AM TO 11:50 AM

Infrared-based ATR

Session Chair: **Abhijit Mahalanobis,**
Lockheed Martin Missiles and Fire Control (USA)

Performance of quantization-based ATR algorithms, Matt S. Horvath, Brian D. Rigling, Wright State Univ. (USA) . . . . [9476-21]

Performance and time requirement analysis of top-hat transform based small target detection, Ozan Yardımcı, Roketsan Roket Sanayii ve Ticaret A.S. (Turkey); Ilkay Ulusoy Parnas, Middle East Technical Univ. (Turkey); Seyit Tunc, Roketsan Roket Sanayii ve Ticaret A.S. (Turkey) . . . . [9476-22]

An evaluation of open set recognition for FLIR images, Matthew Scherreik, Brian D. Rigling, Wright State Univ. (USA) . . . . [9476-23]

Automatic solar panel recognition and defect detection using infrared imaging, Xiang Gao, Eric Munson, Arizona State Univ. (USA); Glen Abousleman, General Dynamics C4 Systems (USA); Jennie Si, Arizona State Univ. (USA). . . . . [9476-24]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:30 pm

Award Presentation . . . . 1:30 PM TO 1:40 PM

2015 ATR BEST PAPER AWARD

Session Chair: **Firooz A. Sadjadi,**
Lockheed Martin Advanced Technology Labs. (USA)

Lockheed Martin Corporation has generously offered to sponsor the Best Paper Awards for the Automatic Target Recognition (ATR) conference. Two awards are planned: the first is the overall Best Paper Award, and the second is a Best Student Paper Award.

Award Sponsored by

LOCKHEED MARTIN

SESSION 7 . . . . TUE 1:40 PM TO 5:40 PM

Advanced Concepts on ATR I

Session Chair: **Andre U. Sokolnikov,**
Visual Solutions and Applications (USA)

Estimation, tracking and geolocation of maritime burst signals from a single receiver *(Invited Paper)*, Douglas J. Nelson, National Security Agency (USA); Jeffrey N. Townsend, U.S. Dept. of Defense (USA) . . . . [9476-25]

Multisensor fusion with the ramification algorithm *(Invited Paper)*, Andre U. Sokolnikov, Visual Solutions and Applications (USA) . . . . [9476-26]

Distributed estimation of a parametric field with random sensor placements *(Invited Paper)*, Marwan Alkhweldi, Zhicheng Cao, Natalia A. Schmid, West Virginia Univ. (USA) . . . . [9476-27]

New algorithms for de-dispersion and signal detection in PAFs: experimenting with inferential statistics *(Invited Paper)*, Natalia A. Schmid, West Virginia Univ. (USA) . . . . [9476-28]

Composite multi-lobe descriptor for cross spectral face recognition: matching active IR to visible light images *(Invited Paper)*, Zhicheng Cao, Natalia A. Schmid, West Virginia Univ. (USA) . . . . [9476-29]

Identification of partially occluded firearms through partonomy *(Invited Paper)*, Nikolay M. Sirakov, Texas A&M Univ.-Commerce (USA) . . . . . . [9476-30]

Ramification algorithm for graphene sample-defect localization *(Invited Paper)*, Andre U. Sokolnikov, Visual Solutions and Applications (USA) . [9476-31]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

An estimation of distribution method for dynamic programming algorithm based on Copulas, Shuo Wang, Yiqun Zhang, China Aerospace Science & Industry Corp. (China) . . . . [9476-32]

Fast algorithm of infrared small target detection in jitter background, Weiping Yang, Xinping Lu, Jicheng Li, National Univ. of Defense Technology (China) . . . . [9476-33]

Image feature extraction based multiple ant colonies cooperation, Zhilong Zhang, Weiping Yang, Jicheng Li, National Univ. of Defense Technology (China) . . . . [9476-34]

Spherical Gaussian mixture model and object tracking system for PTZ camera, Hwangbo Seok, Chan-Su Lee, Yeungnam Univ. (Korea, Republic of) . . . . [9476-35]

Improved Boolean map visual theory based IR ground target detection, Yun-Ji Lim, Sungho Kim, Yeungnam Univ. (Korea, Republic of) . . . . . . [9476-36]

Wednesday 22 April

SESSION 8 . . . . WED 8:00 AM TO 12:30 PM

Advanced Concepts on ATR II

Session Chair: **Andre U. Sokolnikov,**
Visual Solutions and Applications (USA)

Metal-organic hybrid metamaterial THz imaging detectors etching, dramitically increasing the speed and lowering the cost of production of such FPAs *(Invited Paper)*, Dragoslav Grbovic, Fabio Alves, Gamani Karunasiri, Naval Postgraduate School (USA). . . . . [9476-37]

THz devices based on 2D electron systems *(Invited Paper)*, Huili Grace Xing, Univ. of Notre Dame (USA) . . . . [9476-38]

Graphene active plasmionics for terahertz device applications *(Invited Paper)*, Taiichi Taiichi Otsuji, Tohoku Univ. (Japan) . . . . [9476-39]

Terahertz nonlinear optics of graphene and 3D topological insulators *(Invited Paper)*, Alexey A. Belyanin, Texas A&M Univ. (USA); Xianghan Yao, Mikhail D. Tokman, Institute of Applied Physics (Russian Federation) . . [9476-40]

Electronics above 100 GHz *(Invited Paper)*, William D. Palmer, Microsystem Technology Office (USA) . . . . [9476-41]

Toward low-loss, infrared and THz nanophotonics and metamaterials: surface photon polariton modes in polar dielectric crystals *(Invited Paper)*, Joshua D. Caldwell, U.S. Naval Research Lab. (USA) . . . . [9476-42]

Terahertz science and technology of carbon nanomaterials *(Invited Paper)*, Junichiro Kono, Rice Univ. (USA) . . . . [9476-43]

CONFERENCE 9477

Wednesday–Thursday 22–23 April 2015 • Proceedings of SPIE Vol. 9477

Optical Pattern Recognition XXVI

Conference Chairs: **David Casasent,** Carnegie Mellon Univ. (USA); **Mohammad S. Alam,** Univ. of South Alabama (USA)

Program Committee: **Vijayan K. Asari,** Univ. of Dayton (USA); **Tien-Hsin Chao,** Jet Propulsion Lab. (USA); **Katsushi Ikeuchi,** The Univ. of Tokyo (Japan); **Bahram Javidi,** Univ. of Connecticut (USA); **Jed Khoury,** Lardec Inc. (USA); **Wesam A. Sakla,** Air Force Research Lab. (USA); **Yunlong Sheng,** Univ. Laval (Canada); **Robert C. Stirbl,** Jet Propulsion Lab. (USA); **Ashit Talukder,** National Institute of Standards and Technology (USA); **B. V. K. Vijaya Kumar,** Carnegie Mellon Univ. (USA); **Rupert C. Young,** Univ. of Sussex (United Kingdom)

Wednesday 22 April

SESSION 1. . . . . WED 8:30 AM TO 10:30 AM

Invited Session

Session Chair: **David Casasent,** Carnegie Mellon Univ. (USA)

Holographic 3D tracking of microscopic tools *(Invited Paper)*, Jesper Glückstad, Technical Univ. of Denmark (Denmark). . . . . [9477-1]

Efficient live-face detection to counter spoof attack in face recognition systems *(Invited Paper)*, Bikram K. Biswas, Mohammad S. Alam, Univ. of South Alabama (USA) . . . . [9477-2]

Recent results of a medium wave infrared compressive imaging sensor *(Invited Paper)*, Richard Shilling, Robert R. Muise, Lockheed Martin Missiles and Fire Control (USA) . . . . [9477-3]

Advanced big data research through measurements and multi-stakeholder evaluations *(Invited Paper)*, Ashit Talukder, National Institute of Standards and Technology (USA) . . . . [9477-4]

DEDICATED EXHIBITION TIME AND LUNCH BREAK
10:00 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 2 . . . . .WED 1:00 PM TO 2:30 PM

Distortion Invariant Filters: Techniques and Applications

Session Chair: **Rupert Young,** Univ. of Sussex (United Kingdom)

Comparison of spatial domain optimal trade-off maximum average correlation height (OT-MACH) with scale invariant feature transform (SIFT) using images with poor contrast and large illumination gradient *(Invited Paper)*, Akber A. Gardezi, COMSATS Institute of Information Technology (Pakistan) and Univ. of Sussex (United Kingdom); Tabassum-Ur-Razaq Qureshi, Ahmad T. Alkandri, Rupert Young, Philip Birch, Christopher Chatwin, Univ. of Sussex (United Kingdom) . . . . [9477-5]

A robust fringe-adjusted joint transform correlator for efficient object detection, Paheding Sidike, Vijayan K. Asari, Univ. of Dayton (USA); Mohammad S. Alam, Univ. of South Alabama (USA) . . . . [9477-6]

Framework for crowd detection through correlation filters, Saad Rehman, National Univ. of Sciences and Technology (Pakistan); Rupert Young, Univ. of Sussex (United Kingdom) . . . . [9477-7]

Object detection in color images with extended maximum average correlation height filter, Sharif M. A. Bhuiyan, Jesmin F. Khan, Tuskegee Univ. (USA); Mohammad S. Alam, Univ. of South Alabama (USA). . . . . [9477-8]

SESSION 3 . . . . .WED 2:30 PM TO 3:30 PM

Novel Detection Techniques

Session Chair: **Jed Khoury,** Lartec, Inc. (USA)

Simulation of pattern and defect detection in periodic amplitude and phase structures using photo-refractive four-wave mixing, Georges T. Nehmetallah, The Catholic Univ. of America (USA); Partha P. Banerjee, Univ. of Dayton (USA); Jed Khoury, Air Force Research Lab. (USA) . . . . [9477-9]

Efficient thermal image segmentation through integration of nonlinear intensity enhancement with unsupervised active contour model, Fatema A. Albalooshi, Evan Krieger, Paheding Sidike, Vijayan K. Asari, Univ. of Dayton (USA) . . . . [9477-10]

An improved algorithm for pedestrian detection, Prakash Duraisamy, Rochester Institute of Technology (USA); Amr Elgendy, Alexandria Univ. (Egypt) . . . . [9477-11]

SESSION 4 . . . . WED 4:00 PM TO 6:00 PM

Classification and Recognition Techniques

Session Chair: **Wesam A. Sakla,** Air Force Research Lab. (USA)

Gaussian-weighted neighborhood connectivity of nonlinear line attractor for learning complex manifolds, Theus Aspiras, Univ. of Dayton (USA); Wesam A. Sakla, Air Force Research Lab. (USA); Vijayan K. Asari, Univ. of Dayton (USA). . . . . [9477-12]

Volume component analysis for classification of lidar data, Nina M. Varney, Vijayan K. Asari, Univ. of Dayton (USA). . . . . [9477-13]

Machine vision for airport runway identification, Matt Schubert, Andrew J. Moore, Chester Dolph, Glenn Woodell, NASA Langley Research Ctr. (USA) . . . . [9477-14]

Road sign recognition using Viapix module and correlation technique, Yousri Ouerhani, ISEN Brest (France) and ACTRIS (France); M. Desthieux, ACTRIS (France) and ISEN Brest (France); Ayman Alfalou, ISEN Brest (France) . . . . [9477-15]

Fourier transform-based method for pattern matching: affine invariance and beyond, Madhuri Gundam, Dimitrios Charalampidis, Univ. of New Orleans (USA) . . . . [9477-16]

An empirical comparison of K-SVD and GMRA for dictionary learning, Vipin Vijayan, Univ. of Notre Dame (USA); Wesam A. Sakla, Air Force Research Lab. (USA) . . . . [9477-17]

Thursday 23 April

SESSION 5 . . . . THU 8:40 AM TO 10:00 AM

Applications

Session Chairs: **Mohammad S. Alam,** Univ. of South Alabama (USA); **Tien-Hsin Chao,** Jet Propulsion Lab. (USA)

Numerical implementation of the multiple-image optical compression and encryption technique, Yousri Ouerhani, ACTRIS (France) and ISEN Brest (France); Mohammed R. Aldossari, Ayman Alfalou, ISEN Brest (France); Christian Brosseau, Univ. de Bretagne Occidentale (France). . . . . [9477-18]

Night time monitoring using registration of RGB cameras and infrared cameras, Prakash Duraisamy, Rochester Institute of Technology (USA) . . . . [9477-19]

Calculation of key reduction for B92 QKD protocol, Miralem Mehic, Miroslav Voznak, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . . [9477-20]

Adaptive threshold and error-correction coding for robust data retrieval in optical media, Thomas T. Lu, Jet Propulsion Lab. (USA); Colin Costello, California State Polytechnic Univ., Pomona (USA); Matthew Ginley-Hidinger, Occidental College (USA); Tien-Hsin Chao, Jet Propulsion Lab. (USA) . [9477-21]

SESSION 6 . . . . THU 10:30 AM TO 12:00 PM

Novel Optical Memory Systems and New Spatial Light Modulators

Session Chairs: **Tien-Hsin Chao,** Jet Propulsion Lab. (USA); **Jed Khoury,** Lartec, Inc. (USA)

Alignment-free all solid state multiplexed holographic memory systems and applications *(Invited Paper)*, Stuart Yin, The Pennsylvania State Univ. (USA); Claire Luo, General Opto Solutions, LLC (USA). . . . . [9477-22]

Real-time content addressable holographic memory, Tien-Hsin Chao, Thomas T. Lu, George F. Reyes, Jet Propulsion Lab. (USA) . . . . [9477-23]

Design and optimization of an optically driven, deformable mirror device under DC bias, Jarrett Vella Jr., Jed Khoury, Bahareh Haji-saeed, Air Force Research Lab. (USA) . . . . [9477-24]

Prototyping honeycomb deformable mirror actuated optically through a cascade with a heterojunction detector, Jarrett Vella Jr., Jed Khoury, Air Force Research Lab. (USA). . . . . [9477-25]

THURSDAY EVENING . . . . 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

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A new method of pose estimate of non-cooperative target without feature tracking, Jie Liu, Huazhong Univ. of Science and Technology (China); Zongming Liu, Shan Lu, Shanghai Key Lab. of Aerospace Intelligent Control Technology (China) and Shanghai Academy of Space Flight Technology (China); Nong Sang, Huazhong Univ. of Science and Technology (China) . . . . . [9477-26]

Pose estimation of non-cooperative targets based on docking surface, Wenkai Du, Huazhong Univ. of Science and Technology (China); Zongming Liu, Yu Zhang, Shuqing Cao, Shanghai Academy of Space Flight Technology (China); Nong Sang, Huazhong Univ. of Science and Technology (China) . . . . [9477-27]

Detection of weak edges using image registration, Prakash Duraisamy, Rochester Institute of Technology (USA) . . . . [9477-28]

Invariant correlation filters with peak stability parameter in problem of scaled objects recognition, Petr A. Ivanov, Yaroslavl State Univ. (Russian Federation) . . . . [9477-29]

Real-time holographic heterodyne spatial filtering, Jed Khoury, Lartec, Inc. (USA) . . . . [9477-30]

CONFERENCE 9478

Tuesday 21 April 2015 • Proceedings of SPIE Vol. 9478

Modeling and Simulation for Defense Systems and Applications X

Conference Chair: **Eric J. Kelmelis,** EM Photonics, Inc. (USA)

Program Committee: **James P. Durbano,** Northrop Grumman (USA); **James N. Elele,** Naval Air Systems Command (USA); **Susan Harkrider,** U.S. Army Night Vision & Electronic Sensors Directorate (USA); **Jonathan D. Rogers,** Georgia Institute of Technology (USA); **Robert Wright,** Capella Univ. (USA); **Chen Wu,** Defence Research and Development Canada, Ottawa (Canada)

TUESDAY 21 APRIL

SESSION 1. . . . . .TUE 8:40 AM TO 10:00 AM

Mobile and Communications

Secure communication systems using synchronized Lorenz strange attractor on reconfigurable hardware, Marc M. Sepantaie, Esam El-Araby, Georges Nehmatallah, Nader M. Namazi, Amir M. Sepantaie, The Catholic Univ. of America (USA) . . . . [9478-1]

Dynamic fair node spectrum allocation for ad hoc networks using random matrices, Mark D. Rahmes, George Lemieux, Dave Chester, Harris Corp. (USA); Jerome Sonnenberg, Harris Corp. GCSD (USA) . . . . [9478-2]

Certificate based key agreement among LTE entities for secure handover, Divya Mohan, B. Sridevi, Velammal College of Engineering and Technology (India) . . . . [9478-3]

Weaknesses in Android certificate security, Daniel E. Krych, Stephen Lange-Maney, Patrick McDaniel, The Pennsylvania State Univ. (USA); William Glodek, U.S. Army Research Lab. (USA) . . . . [9478-4]

SESSION 2 . . . . .TUE 10:30 AM TO 11:50 AM

Algorithms, Platforms, and Tools

Adaptive OpenCL libraries for platform portability, Paul A. Fox, Allyssa L. Batten, Stephen Kozacik, Eric J. Kelmelis, EM Photonics, Inc. (USA) . . . [9478-5]

Enhanced NVESD EO/IR sensor acquisition life cycle test and evaluation process, Jonathan G. Hixson, Christopher May, U.S. Army Night Vision & Electronic Sensors Directorate (USA) . . . . [9478-6]

An evaluation of algorithms and methods for compressing and decompressing atmospheric transmission data for use in at-sensor measurements, Mark H. Van Benthem, Drew P. Woodbury, Sandia National Labs. (USA) . . . . [9478-7]

Power aware computing: a directive-based approach, Paul A. Fox, Stephen Kozacik, James Bonnett, Eric J. Kelmelis, EM Photonics, Inc. (USA). . . . [9478-8]

Lunch/Exhibition Break . . . . Tue 11:50 am to 1:20 pm

SESSION 3 . . . . .TUE 1:20 PM TO 3:00 PM

Systems and Environments I

A reference model for critical infrastructure protection system (CIPS), YoungDon Shin, Samsung Thales Co., Ltd. (Korea, Republic of); Cheol-Young Park, George Mason Univ. (USA); Jae-Chon Lee, Ajou Univ. (Korea, Republic of) . . . . [9478-9]

Modeling and simulation of infrastructure resiliency against man-made hazards, Yahia Al-Smadi, Texas A&M Univ.-Kingsville (USA) . . . . [9478-10]

Focus on connections for successful organizational transformation to model based engineering, Guy Babineau, Northrop Grumman Corp. (USA) . . . . [9478-11]

The effectiveness of the jammer signal characteristics on Conical-Scan systems, Mehmet C. Sahingil, Murat S. Aslan, TÜBİTAK BİLGEM İLTAREN (Turkey) . . . . [9478-12]

Understanding the impact of blasts from explosions on MEMS, Yahia Al-Smadi, Texas A&M Univ.-Kingsville (USA) . . . . [9478-13]

SESSION 4 . . . . .TUE 3:30 PM TO 5:10 PM

Systems and Envrionments II

Target detection and tracking in maritime surveillance mission, Madeleine G. Sabordo, Elias Aboutanios, The Univ. of New South Wales (Australia). . . . . [9478-14]

Virtual sensor tracking using byzantine fault tolerance and predictive outlier model for complex tasks recognition, Vasanth Iyer, Sachin Shetty, Tennessee State Univ. (USA) . . . . [9478-15]

Metamaterial based narrowband perfect absorbers, Ahmed S. Sharkawy, Mathew Zablocki, Lumilant, Inc. (USA) . . . . [9478-16]

The use of a low-cost, visible light 3D scanner to create virtual reality environment models of actors and objects, Jeremy Straub, Univ. of North Dakota (USA). . . . . [9478-17]

Physical environment virtualization test bed for human activities recognition, Azin Poshtkar, Vinayak Elangovan, Amir Shirkhodaie, Tennessee State Univ. (USA); Alex L. Chan, Shuowen Hu, U.S. Army Research Lab. (USA) . . . . [9478-18]

INTERACTIVE POSTER SESSION

TUESDAY EVENING. 6:00 PM TO 7:30 PM

All symposium attendees – You are invited to attend the evening Interactive Poster Session to view the high-quality posters and engage the authors in discussion. Enjoy light refreshments while networking with colleagues in your field. Authors may set up their posters between 7:30 am and 12:00 noon the day of their poster session. Special daytime previewing prior to the session from 12:00 noon to 4:30 pm. Attendees are required to wear their conference registration badges to access Level 200, Mezzanine to view the posters.

Posters that are not set up by the 5:00 pm cut-off time will be considered no-shows, and their manuscripts may not be published. Poster authors should accompany their posters from 6:00 to 7:30 pm to answer questions from attendees. All posters and other materials must be removed no later than 8:00 pm. Any posters or materials left behind at the close of the poster session will be considered unwanted and will be discarded. SPIE assumes no responsibility for posters left up after the end of each poster session.

Building GSM network in extreme conditions, Martin Mikulec, Miroslav Voznak, Marcel Fajkus, Pavol Partila, Jiri Slachta, Zdenka Chmelikova, VŠB-Technical Univ. of Ostrava (Czech Republic) . . . . [9478-19]

CONFERENCE 9479

Tuesday–Thursday 21–23 April 2015 • Proceedings of SPIE Vol. 9479

Open Architecture/Open Business Model Net Centric Systems and Defense Transformation 2015

Conference Chair: **Raja Suresh,** General Dynamics Advanced Information Systems (USA)

Program Committee: **Robert Bond,** MIT Lincoln Lab. (USA); **Vasu D. Chakravarthy,** Air Force Research Lab. (USA); **Megan Cramer,** U.S. Navy PEO LCS (USA); **John S. Eicke,** U.S. Army Research Lab. (USA); **Thomas Green,** SAIC (USA); **Nickolas Guertin,** U.S. Navy (USA); **Michael A. Kolodny,** U.S. Army Research Lab. (USA); **Leo J. Rose,** U.S. Air Force (USA); **Jason R. Stack,** Office of Naval Research (USA)

Tuesday 21 April

SESSION 1. . . . . TUE 8:30 AM TO 11:40 AM

Affordability Considerations in Military Systems

Session Chair: **Roy H. Olsson III,** DARPA (USA)

Reconfigurable technologies and architectures for phased array antennas: an overview of the DARPA ACT program *(Invited Paper)*, Roy H. Olsson III, Defense Advanced Research Projects Agency (USA). . . . . [9479-1]

Methodologies to analyze and explore the impact of technological and operational changes on the fully burdened cost structure of the global force structure *(Invited Paper)*, Mitchell W. Kossar, Benjamin Rogers, First Principles Advisory Group (USA). . . . . [9479-2]

GTRI software defined modular array antenna, Richard T. Lee, Ryan S. Westafer, Georgia Tech Research Institute (USA) . . . . [9479-3]

Optically-controlled GeTe phase change switch and its applications in reconfigurable antenna arrays, Loc Chau, James Ho, Xing Lan, Northrop Grumman Aerospace Systems (USA); Robert M. Young, Doyle Nichols, Nabil El-Hinnawy, Northrop Grumman Electronic Systems (USA); Nima Ghalichechian, John Volakis, The Ohio State Univ. (USA). . . . . [9479-4]

Impact - a low cost, reconfigurable, digital beamforming common module building block for next generation phased arrays, Lee Paulsen, Ted Hoffmann, Charlie Nguyen, Rockwell Collins, Inc. (USA) . . . . [9479-5]

Higher-order N-path filters and active cancellation techniques for interference mitigation and STAR in digital array receivers, Harish Krishnaswamy, Jin Zhou, Negar Reiskarimian, Columbia Univ. (USA) . . . [9479-6]

Vanadium dioxide phase change switches, Mark Field, Christopher Hillman, Philip Stupar, Jonathan Hacker, Zachary Griffith, Teledyne Scientific Co. (USA); Kang-Jin Lee, Teledyne Scientific & Imaging, LLC (USA) . . . . [9479-7]

Lunch/Exhibition Break . . . . 11:40 am to 1:00 pm

SESSION 2 . . . . TUE 1:00 PM TO 3:10 PM

Open Architecture Systems

Session Chairs: **Jason R. Stack,** Office of Naval Research (USA); **Megan A. Cramer,** U.S. Navy (USA)

DOD product lines: a holistic strategy for defense open business models *(Invited Paper)*, Robert Matthews, Naval Air Systems Command (USA). . [9479-8]

A systems approach to achieving the benefits of open and modular systems, Gavin Pearson, Defence Science and Technology Lab. (United Kingdom); Richard Smith, IBM United Kingdom Ltd. (United Kingdom); Howard Tripp, Chemring EOD Ltd. (United Kingdom) . . . . [9479-9]

Q-learning and p-persistent CSMA based MAC protocol for cognitive radio networks operating with shared spectrum activity, Clifton L. Watson, Air Force Research Lab. (USA); Subir Biswas, Michigan State Univ. (USA). [9479-10]

Open architecture design and approach for the integrated sensor architecture (ISA), Christine L. Moulton, U.S. Army Night Vision & Electronic Sensors Directorate (USA); Jared J. Hepp, John Harrell, Oakwood Controls (USA); Michael Kogut, SAIC (USA) . . . . [9479-11]

Architecting open AUV systems, Dani Goldberg, Bluefin Robotics Corp. (USA) . . . . [9479-12]

Modular open RF architecture: extending VICTORY to RF systems, Jason Dirner, Vistronix (USA). . . . . [9479-13]

Wednesday 22 April

SESSION 4 . . . . WED 8:30 AM TO 10:30 AM

Self-organizing Collaborative Unmanned ISR Teams I

Joint Session with Conferences 9479 and 9468

Session Chairs: **Raja Suresh,** General Dynamics Advanced Information Systems (USA); **Robert E. Karlsen,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA)

DARPA perspective on open architectures *(Invited Paper)*, John Shaw, Defense Advanced Research Projects Agency (USA). . . . . [9479-14]

Open mission system overview *(Invited Paper)*, Eric Koper, U.S. Air Force (USA) . . . . [9479-15]

Overview of DARPA CODE program *(Invited Paper)*, Jean-Charles Lede, Defense Advanced Research Projects Agency (USA). . . . . [9479-16]

Open architecture flexible weapons *(Invited Paper)*, Jonathan Shaver, Air Force Research Lab. (USA) . . . . [9479-17]

DEDICATED EXHIBITION TIME AND LUNCH BREAK . . . . 10:30 AM TO 1:00 PM

Enjoy Wednesday morning coffee break with a complimentary continental breakfast while walking the exhibition floor and connecting with reps from the largest prime contractors, key suppliers, and dynamic startups. Meet with vendors showcasing their newest products and cutting-edge technologies in optics, photonics, sensing, and imaging. Various food outlets are also located in the DSS Expo Hall and will be open for lunch during Exhibition Hours.

SESSION 5 . . . . WED 1:00 PM TO 3:10 PM

Self-organizing, Collaborative Unmanned ISR Teams II

Joint Session with conferences 9479 and 9468

Session Chairs: **Raja Suresh,** General Dynamics Advanced Information Systems (USA); **Robert E. Karlsen,** U.S. Army Tank Automotive Research, Development and Engineering Ctr. (USA)

Executable architecture management system *(Invited Paper)*, Jeff Monroe, Metron, Inc. (USA) . . . . [9479-18]

UAV field demonstration of social media enabled tactical data link, Christopher C. Olson, Andrew J. Newman, Da Xu, Sean R. Martin, Jonathan C. Castelli, Johns Hopkins Univ. Applied Physics Lab., LLC (USA) . . . . . . [9468-12]

Fuel Cell powered small unmanned aerial systems (UASs) for extended endurance, Deryn D. Chu, Zachary Dunbar, Rongzhong Jiang, U.S. Army Research Lab. (USA) . . . . [9468-13]

Tactical 3D model generation using structure-from-motion on video from unmanned systems, Joshua D. Harguess, Mark Bilinski, Kim B. Nguyen, Darren N. Powell, Susie Alderson, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-14]

Aircraft path planning for optimal imaging using dynamic cost functions, Gordon Christie, Haseeb R. Chaudhry, Kevin Kochersberger, Virginia Polytechnic Institute and State Univ. (USA) . . . . [9468-15]

UxV to the cloud via widgets, Michael August, Darren N. Powell, Charles Yetman, Kim B. Nguyen, Joshua D. Harguess, Mark Bilinski, Space and Naval Warfare Systems Ctr. Pacific (USA) . . . . [9468-16]

DEFENSE + SECURITY

CONFERENCE 9479

Thursday 23 April

SESSION 6 . . . . THU 8:30 AM TO 10:10 AM

MAST: Bio-inspired Control

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Hummingbird flight control under extreme aerodynamic circumstances *(Invited Paper)*, Robert Dudley, Univ. of California, Berkeley (USA) . . . . [9467-58]

A control theoretic approach to neuromorphic computing *(Invited Paper)*, Michael Dorothy, Univ. of Illinois at Urbana-Champaign (USA) . . . . [9467-59]

Bio-inspired sensing and control for disturbance rejection and stabilization *(Invited Paper)*, Gregory Gremillion, James S. Humbert, Univ. of Maryland, College Park (USA) . . . . [9467-60]

High-speed autonomous navigation of unknown environments using learned probabilities of collision *(Invited Paper)*, Charles Richter, Nicholas Roy, Massachusetts Institute of Technology (USA) . . . . [9467-61]

Detecting discrete phenomena using wide field integration methods *(Invited Paper)*, Allison M. Mathis, Joseph K. Conroy, William D. Nothwang, Ryan Robinson, Jared Shamwell, U.S. Army Research Lab. (USA). . . . . [9467-62]

SESSION 7 . . . . THU 10:40 AM TO 12:00 PM

MAST: Scale Legged Locomotion

Joint Session with Conferences 9467, 9468, 9479

Session Chairs: **Christopher M. Kroninger,** U.S. Army Research Lab. (USA); **William D. Nothwang,** U.S. Army Research Lab. (USA)

Dynamic legged locomotion for palm-size robots *(Invited Paper)*, Ronald Fearing, Duncan Haldane, Univ. of California, Berkeley (USA); David Zarrouk, Ben-Gurion Univ. of the Negev (Israel) . . . . [9467-63]

Metastable legged locomotion in real-world environments: methods to quantify and optimize reliability *(Invited Paper)*, Katie Byl, Cenk O. Saglam, Univ. of California, Santa Barbara (USA). . . . . [9467-64]

Scattering of a legged robot in a heterogeneous granular terrain *(Invited Paper)*, Feifei Qian, Daniel I. Goldman, Georgia Institute of Technology (USA) . . . . [9467-65]

Data driven models of legged locomotion *(Invited Paper)*, Shai Revzen, Univ. of Michigan (USA) . . . . [9467-66]

Lunch/Exhibition Break . . . . 12:00 pm to 1:00 pm

SESSION 8 . . . . THU 1:00 PM TO 3:00 PM

ISR Systems

Session Chair: **Raja Suresh,** General Dynamics Advanced Information Systems (USA)

Challenges in RF convergence *(Invited Paper)*, Vincent Sabio, Defense Advanced Research Projects Agency (USA). . . . . [9479-19]

Development of a video SAR for FMV through clouds *(Invited Paper)*, H. Bruce Wallace, Defense Advanced Research Projects Agency (USA) . . . . [9479-20]

Embedded cooling for defense electronics *(Invited Paper)*, Avram Bar-Cohen, Defense Advanced Research Projects Agency (USA). . . . . [9479-21]

A common open systems architecture for ISR sensor payloads *(Invited Paper)*, Gibbs Dickson, U.S. Air Force (USA) . . . . [9479-22]

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- Dimensionality Reduction for Hyperspectral Image Analysis
- Laser Systems Engineering
- Applications and Performance of High Power Lasers in the Battlefield
- Radiometry and its Practical Applications
- Statistics for Imaging and Sensor Data

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IR SENSORS AND SYSTEMS

OPTICAL AND OPTOMECHANICAL ENGINEERING

DEFENSE, HOMELAND SECURITY, AND LAW ENFORCEMENT

DISPLAYS

COURSE INDEX

EMERGING TECHNOLOGIES

IMAGERY AND PATTERN ANALYSIS

IMAGING AND SENSING TECHNOLOGIES

INFORMATION SYSTEMS AND NETWORKS: PROCESSING, FUSION, AND KNOWLEDGE GENERATION

INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE

THIS PROGRAM IS CURRENT AS OF DECEMBER 2014

COURSE INDEX

DAILY COURSE SCHEDULE

IR Sensors and Systems

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC713 **Engineering Approach to Imaging System Design** (Holst) 8:30 am to 5:30 pm, $565 / $660	SC1162 **Design of Multiband Optical Systems** (Unger) 8:30 am to 5:30 pm, $565 / $660	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345
SC152 **Infrared Focal Plane Arrays** (Dereniak, Hubbs) 8:30 am to 5:30 pm, $515 / $610	SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC181 **Predicting Target Acquisition Performance of Electro-Optical Imagers** (Vollmerhausen) 8:30 am to 5:30 pm, $570 / $665	SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	SC067 **Testing and Evaluation of E-O Imaging Systems** (Holst) 8:30 am to 5:30 pm, $595 / $690
SC835 **Infrared Systems - Technology & Design** (Daniels) 8:30 am to 5:30 pm, $1,045 / $1,265		SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC1068 **Introduction to Night Vision** (Browne) 1:30 pm to 5:30 pm, $295 / $345	
SC214 **Infrared Window and Dome Materials** (Harris) 8:30 am to 5:30 pm, $585 / $680	SC1136 **Infrared Optical Materials, Fabrication and Testing for the Optical Engineer** (DeGroote Nelson) 1:30 to 5:30 pm, $295 / $345	SC1109 **Infrared Radiometric Calibration** (Yoon, Eppeldauer, Kaplan, Gibson) 1:30 pm to 5:30 pm, $295 / $345	SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	
SC900 **Uncooled Thermal Imaging Detectors and Systems** (Hanson) 8:30 am to 5:30 pm, $555 / $650	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685			
	SC194 **Multispectral and Hyperspectral Image Sensors** (Lomheim) 8:30 am to 12:30 pm, $375 / $425			

Optical and Optomechanical Engineering

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC713 **Engineering Approach to Imaging System Design** (Holst) 8:30 am to 5:30 pm, $565 / $660	SC1162 **Design of Multiband Optical Systems** (Unger) 8:30 am to 5:30 pm, $565 / $660	SC609 **Basic Optics for Non-Optics Personnel** (Harding) 8:30 am to 11:00 am, $100 / $150		
	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675		
	SC1136 **Infrared Optical Materials, Fabrication and Testing for the Optical Engineer** (DeGroote Nelson) 1:30 to 5:30 pm, $295 / $345	SC1109 **Infrared Radiometric Calibration** (Yoon, Eppeldauer, Kaplan, Gibson) 1:30 pm to 5:30 pm, $295 / $345		
	SC1052 **Optical Systems Engineering** (Kasunic) 8:30 am to 5:30 pm, $595 / $690	SC014 **Introduction to Optomechanical Design** (Vukobratovich) 8:30 am to 5:30 pm, $890 / $1,110		
	SC015 **Structural Adhesives for Optical Bonding** (Daly) 1:30 pm to 5:30 pm, $295 / $345			
	SC010 **Introduction to Optical Alignment Techniques** (Castle) 8:30 am to 5:30 pm, $515 / $610			

DAILY COURSE SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Defense, Homeland Security, and Law Enforcement				
SC1104 **Applications and Performance of High Power Lasers in the Battlefield** (Kalisky) 1:30 pm to 5:30 pm, $295 / $345	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685	SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	SC067 **Testing and Evaluation of E-O Imaging Systems** (Holst) 8:30 am to 5:30 pm, $595 / $690
	SC1162 **Design of Multiband Optical Systems** (Unger) 8:30 am to 5:30 pm, $565 / $660	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675	SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345
	SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC181 **Predicting Target Acquisition Performance of Electro-Optical Imagers** (Vollmerhausen) 8:30 am to 5:30 pm, $570 / $665	SC995 **Target Detection Algorithms for Hyperspectral Imagery** (Nasrabadi) 8:30 am to 5:30 pm, $515 / $610	
			SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	
			SC1068 **Introduction to Night Vision** (Browne) 1:30 pm to 5:30 pm, $295 / $345	
Displays				
SC066 **Fundamentals of Electronic Image Processing** (Weeks) 8:30 am to 5:30 pm, $585 / $680	SC159 **Head-Mounted Displays: Design and Applications** (Melzer, Browne) 8:30 am to 5:30 pm, $515 / $610		SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	
			SC1068 **Introduction to Night Vision** (Browne) 1:30 pm to 5:30 pm, $295 / $345	
Emerging Technologies				
		SC1076 **Analog-to-Digital Converters for Digital ROICs** (Veeder) 8:30 am to 5:30 pm, $515 / $610		

THIS PROGRAM IS CURRENT AS OF DECEMBER 2014

DAILY COURSE SCHEDULE

Imagery and Pattern Analysis

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC160 **Precision Stabilized Pointing and Tracking Systems** (Hilkert) 8:30 am to 5:30 pm, $515 / $610		SC1161 **Dimensionality Reduction for** Hyperspectral Image Analysis (Du) 1:30 pm to 5:30 pm, $295 / $345		

Imaging and Sensing Technologies

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC713 **Engineering Approach to Imaging System Design** (Holst) 8:30 am to 5:30 pm, $565 / $660	SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	SC067 **Testing and Evaluation of E-O Imaging Systems** (Holst) 8:30 am to 5:30 pm, $595 / $690
SC066 **Fundamentals of Electronic Image Processing** (Weeks) 8:30 am to 5:30 pm, $585 / $680	SC1160 **Fundamentals of Fiber Optic Sensor Design and Technology** (Udd, Lieberman) 8:30 am to 5:30 pm, $545 / $640	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675	SC995 **Target Detection Algorithms for Hyperspectral Imagery** (Nasrabadi) 8:30 am to 5:30 pm, $515 / $610	
SC152 **Infrared Focal Plane Arrays** (Dereniak, Hubbs) 8:30 am to 5:30 pm, $515 / $610	SC194 **Multispectral and Hyperspectral Image Sensors** (Lomheim) 8:30 am to 12:30 pm, $375 / $425	SC1109 **Infrared Radiometric Calibration** (Yoon, Eppeldauer, Kaplan, Gibson) 1:30 pm to 5:30 pm, $295 / $345	SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	
SC835 **Infrared Systems - Technology & Design** (Daniels) 8:30 am to 5:30 pm, $1,045 / $1,265		SC1076 **Analog-to-Digital Converters for Digital ROICs** (Veeder) 8:30 am to 5:30 pm, $515 / $610		
SC1072 **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $575 / $670	SC1136 **Infrared Optical Materials, Fabrication and Testing for the Optical Engineer** (DeGroote Nelson) 1:30 to 5:30 pm, $295 / $345			
SC900 **Uncooled Thermal Imaging Detectors and Systems** (Hanson) 8:30 am to 5:30 pm, $555 / $650	SC1162 **Design of Multiband Optical Systems** (Unger) 8:30 am to 5:30 pm, $565 / $660			
	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685			

DAILY COURSE SCHEDULE

Information Systems and Networks: Processing, Fusion, and Knowledge Generation

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
			SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	

Intelligence, Surveillance, and Reconnaissance

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC1103 **3D Imaging Laser Radar** (Kamerman) 8:30 am to 5:30 pm, $515 / $610	SC1162 **Design of Multiband Optical Systems** (Unger) 8:30 am to 5:30 pm, $565 / $660	SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	SC067 **Testing and Evaluation of E-O Imaging Systems** (Holst) 8:30 am to 5:30 pm, $595 / $690
	SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675	SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345
SC160 **Precision Stabilized Pointing and Tracking Systems** (Hilkert) 8:30 am to 5:30 pm, $515 / $610	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685	SC181 **Predicting Target Acquisition Performance of Electro-Optical Imagers** (Vollmerhausen) 8:30 am to 5:30 pm, $570 / $665		
	SC194 **Multispectral and Hyperspectral Image Sensors** (Lomheim) 8:30 am to 12:30 pm, $375 / $425			

Laser Sensors and Systems

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC1103 **3D Imaging Laser Radar** (Kamerman) 8:30 am to 5:30 pm, $515 / $610	SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC1112 **Introduction to Electro-Optical Systems Design** (Stotts) 8:30 am to 5:30 pm, $580 / $675	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345
SC160 **Precision Stabilized Pointing and Tracking Systems** (Hilkert) 8:30 am to 5:30 pm, $515 / $610		SC181 **Predicting Target Acquisition Performance of Electro-Optical Imagers** (Vollmerhausen) 8:30 am to 5:30 pm, $570 / $665	SC1144 **Laser Systems Engineering** (Kasunic) 8:30 am to 5:30 pm, $515 / $610	
SC1104 **Applications and Performance of High Power Lasers in the Battlefield** (Kalisky) 1:30 pm to 5:30 pm, $295 / $345			SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	

Next Generation Sensors and Systems

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC1072 **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $575 / $670	SC1160 **Fundamentals of Fiber Optic Sensor Design and Technology** (Udd, Lieberman) 8:30 am to 5:30 pm, $545 / $640		SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	

Sensing for Industry, Environment, and Health

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC1072 **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $575 / $670	SC1160 **Fundamentals of Fiber Optic Sensor Design and Technology** (Udd, Lieberman) 8:30 am to 5:30 pm, $545 / $640	SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC789 **Introduction to Optical and Infrared Sensor Systems** (Shaw) 8:30 am to 5:30 pm, $515 / $610	
SC713 **Engineering Approach to Imaging System Design** (Holst) 8:30 am to 5:30 pm, $565 / $660	Wed SC1137 **Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation** (Schroeder) 8:30 am to 5:30 pm, $515 / $610	SC1109 **Infrared Radiometric Calibration** (Yoon, Eppeldauer, Kaplan, Gibson) 1:30 pm to 5:30 pm, $295 / $345	SC995 **Target Detection Algorithms for Hyperspectral Imagery** (Nasrabadi) 8:30 am to 5:30 pm, $515 / $610	
	SC1136 **Infrared Optical Materials, Fabrication and Testing for the Optical Engineer** (DeGroote Nelson) 1:30 pm to 5:30 pm, $295 / $345		SC154 **Electro-Optical Imaging System Performance** (Holst) 8:30 am to 5:30 pm, $600 / $695	
	SC1073 **Radiometry and its Practical Applications** (Grant) 8:30 am to 5:30 pm, $590 / $685			
	SC194 **Multispectral and Hyperspectral Image Sensors** (Lomheim) 8:30 am to 12:30 pm, $375 / $425			

Sensor Data and Information Exploitation

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
SC1072 **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $575 / $670	SC194 **Multispectral and Hyperspectral Image Sensors** (Lomheim) 8:30 am to 12:30 pm, $375 / $425	SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345
SC160 **Precision Stabilized Pointing and Tracking Systems** (Hilkert) 8:30 am to 5:30 pm, $515 / $610		SC1076 **Analog-to-Digital Converters for Digital ROICs** (Veeder) 8:30 am to 5:30 pm, $515 / $610	SC995 **Target Detection Algorithms for Hyperspectral Imagery** (Nasrabadi) 8:30 am to 5:30 pm, $515 / $610	

DAILY COURSE SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Signal & Image Processing				
SC066 **Fundamentals of Electronic Image Processing** (Weeks) 8:30 am to 5:30 pm, $585 / $680		SC1161 **Dimensionality Reduction for Hyperspectral Image Analysis** (Du) 1:30 pm to 5:30 pm, $295 / $345	SC1135 **Multispectral Image Fusion and Night Vision Colorization** (Zheng, Blasch) 8:30 am to 12:30 pm, $295 / $345	
SC1072 **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $575 / $670		SC1076 **Analog-to-Digital Converters for Digital ROICs** (Veeder) 8:30 am to 5:30 pm, $515 / $610	SC995 **Target Detection Algorithms for Hyperspectral Imagery** (Nasrabadi) 8:30 am to 5:30 pm, $515 / $610	
Courses for Industry & Exhibitors				
		SC609 **Basic Optics for Non-Optics Personnel** (Harding) 8:30 am to 11:00 am, $100 / $150		SC972 **Basic Laser Technology** (Sukuta) 8:30 am to 12:30 pm, $295 / $345

IR Sensors and Systems

Design of Multiband Optical Systems

New

SC1162

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Multispectral and hyperspectral systems are designed to increase target acquisition performance as well as answer SWaP-C (size/weight/power/cost) requirements for defense and remote sensing systems. Recent developments in optical materials enable optical systems that operate over multiple infrared bands simultaneously. This course describes techniques for designing these systems using existing and new chalcoginide materials, and it provides methods for choosing material combinations, laying out systems, and predicting performance. An emphasis is placed on understanding dispersion and thermal characteristics in order to design achromatic and athermalized dual- and multi-band infrared imaging systems. Additionally, this course will touch upon recent advances in fused, layered, and gradient index infrared optics, specifically with regard to chalcoginide materials.

LEARNING OUTCOMES

This course will enable you to:
- lay out lenses using first order optical design methods
- determine a working set of optical materials based on optical and thermal characteristics
- construct glass maps for dual-band solutions
- optimize glass types using private catalog materials and optimize systems by employing user-defined merit function constraints
- describe axial and radial gradient index infrared materials and explain the advantages/disadvantages of each type

INTENDED AUDIENCE

This course is intended for optical designers and engineers wishing to expand their knowledge of infrared and multiband optics, materials, and design principles. A working understanding of optical design methods and experience with optical design software is recommended.

INSTRUCTOR

Blair Unger is Senior Optical Designer at ASE Optics. He has authored and co-authored papers and patents covering a variety of topics ranging from design of infrared chalcoginide systems to novel solar concentrators. He earned a Ph.D. in Optics at the University of Rochester, Institute of Optics. Dr. Unger is a member of both OSA and SPIE.

COURSE PRICE INCLUDES the text *Optical Design Fundamentals for Infrared Systems, Second Edition* (SPIE, 2001) by Max Riedl.

Infrared Focal Plane Arrays

Updated in 2015

SC152

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

The course presents a fundamental understanding of two-dimensional arrays applied to detecting the infrared spectrum. The physics and electronics associated with 2-D infrared detection are stressed with special emphasis on the hybrid architecture unique to two-dimensional infrared arrays.

LEARNING OUTCOMES

This course will enable you to:
- develop the building blocks of 2-D arrays
- explain charge transfer concepts of various architectures
- describe various input electronics circuits
- discuss testing techniques used in the IR for 2-D arrays
- provide an overview of current technologies
- demonstrate aliasing effects
- describe digital FPAs
- review room-temperature thermal arrays
- review uncooled photon arrays
- discuss dual band arrays
- discuss small pixel pitch devices
- review HOT devices
- compare II-VI vs. III-V devices

INTENDED AUDIENCE

This material is intended for engineers, scientists and project managers who need to learn more about two-dimensional IR arrays from a user's point of view. It gives the student insight into the optical detection process, as well as what is available to application engineers, advantages, characteristics and performance.

INSTRUCTOR

Eustace Dereniak is a Professor of Optical Sciences and Electrical and Computer Engineering at the University of Arizona, Tucson, AZ. His research interests are in the areas of detectors for optical radiation, imaging spectrometers and imaging polarimeters instrument development. Dereniak is a co-author of several textbooks and has authored book chapters. His publications also include over 100 authored or co-authored refereed articles. He spent many years in industrial research with Raytheon, Rockwell International, and Ball Brothers Research Corporation. He has taught extensively and is a Fellow of the SPIE and OSA, and a member of the Board of Directors of SPIE.

John Hubbs is an engineer at the Infrared Radiation Effects Laboratory (IRREL). Dr. Hubbs has over 30 years of experience characterizing focal plane arrays (FPAs) in both clear and radiation environments. His research interests are in the areas of detectors for optical radiation and radiation effects on infrared focal plane arrays, which has resulted in the publication of over 75 papers. He is a Fellow of the SPIE and the Military Sensing Symposium (MSS).

Radiometry and its Practical Applications

Updated in 2015

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:
- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

Analog-to-Digital Converters for Digital ROICs

Updated in 2015

SC1076

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors. Attendees will learn how to evaluate ADC architectures using basic figures of merit for use in different sensor formats. We will cover a wide range of cutting edge architectures and see published examples without delving into transistor level theory. We will survey both academia and industrial ADC architectures. From this survey attendees will discover the industrial design evolution convergence down to a few workhorse architectures and what lessons it imparts to the image sensor community. If you are interested in the digital ROIC revolution or if you ever interface with designers or evaluate digital ROIC proposals, then you will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:

- identify analog-to-digital architectures used for creating digital ROICs and image sensors
- calculate ADC architecture figures of merit important to image sensors
- evaluate ADC architecture compatibility with image sensor format and requirements
- infer the direction in which state-of-the-art digital image sensors are headed
- name the top ADC architectures used by commercial industry and explain how this knowledge benefits the image sensor industry
- stimulate your own creativity and help you develop new ideas and applications for digital ROICs and digital image sensors

INTENDED AUDIENCE

This course is intended for engineers and physicists with a background in basic electrical theory (electrical stimuli, resistors, capacitors and block diagramming) who wish to learn about analog-to-digital converter architectures and how they are applied to digital ROICs and digital image sensors. An undergraduate degree in science or engineering is assumed, and basic knowledge of electrical engineering will be particularly helpful.

INSTRUCTOR

Kenton Veeder is a ROIC design engineer, systems engineer, and part time detector physicist. He has been in the defense and commercial image sensor field for over 12 years and is the president of Senseeker Engineering Inc. in Santa Barbara, California. He has nine patents and several publications, one of which earned the MSS Detectors best paper award in 2006. While working for Raytheon he was awarded recognition as Raytheon's 'Father of the Digital Focal Plane Array' and he and his team were given the company wide 'Excellence In Technology' award. Kenton earned his M.S. in electrical engineering from the Analog-and-Mixed Signal Center at Texas A&M University. Kenton is a member of SPIE and IEEE.

Infrared Window and Dome Materials

Updated in 2015

SC214

Course Level: Advanced
CEU: 0.65 $585 Members | $680 Non-Members USD
Monday 8:30 am to 5:30 pm

This course presents an overview of the optical, thermal and mechanical characteristics of infrared-transmitting window and dome materials. Other topics include thermal shock response, rain and particle erosion, protective coatings, antireflection coatings, electromagnetic shielding, proof testing, and fabrication of optical ceramics. The course concludes with a brief discussion of sapphire and diamond as infrared materials.

LEARNING OUTCOMES

This course will enable you to:

- identify the optical, thermal and mechanical characteristics of a window material that are critical to its selection for a particular application
- predict optical, thermal and mechanical performance of window materials under a range of conditions, based on tabulated data
- compare the strengths and weaknesses of different materials and different coatings for a given application
- describe the principal methods by which optical ceramics are manufactured

INTENDED AUDIENCE

The course is directed at engineers, scientists, managers and marketing personnel who need an introduction to properties, performance, and manufacture of windows and domes. A basic degree in engineering or science is the expected background, but care will be taken to provide introductory background information for each topic.

INSTRUCTOR

Daniel Harris is a Senior Scientist at the Naval Air Warfare Center, China Lake, California, where he directs programs in optical materials.

COURSE PRICE INCLUDES the text *Materials for Infrared Windows and Domes* (SPIE Press, 1999) by Daniel Harris.<br<<br<Attendees should bring a calculator to this course.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Infrared Systems - Technology & Design

SC835

Course Level: Advanced
CEU: 1.3 $1,045 Members | $1,265 Non-Members USD
Monday - Tuesday 8:30 am to 5:30 pm

This course covers the range of topics necessary to understand the theoretical principles of modern infrared-technology. It combines numerous engineering disciplines necessary for the development of infrared systems. Practical engineering calculations are highlighted, with examples of trade studies illustrating the interrelationships among the various hardware characteristics.

This course is comprised of four sections:

Section 1 introduces the geometrical optics concepts including image formation, stops and pupils, thick lenses and lens combinations, image quality, and the properties of infrared materials.

Section 2 covers the essentials of radiometry necessary for the quantitative understanding of infrared signatures and flux transfer. These concepts are then developed and applied to flux-transfer calculations for blackbody, graybody, and selective radiator sources. Remote temperature calibrations and measurements are then used as an illustration of these radiometric principles.

Section 3 is devoted to fundamental background issues for optical detection-processes. It compares the characteristics of cooled and uncooled detectors with an emphasis on spectral and blackbody responsivity, detectivity (D*), as well as the noise mechanisms related to optical detection. The detector parameters and capabilities of single detectors and third generation focal plane arrays (FPAs) are analyzed.

With this acquired background, Section 4 considers the systems-design aspects of infrared imagers. The impact of scan format on signal-to-noise ratio is described, and the engineering tradeoffs inherent in the development of infrared search and track (IRST) systems are explained. Figures of merit such as MTF, NETD, and MRTD of staring arrays are examined for the performance metrics of thermal sensitivity and spatial resolution of thermal imaging systems (TIS). Contrast threshold functions based on Johnson and visible cycles (often denoted as N- and V-cycles) are specified. The interrelationships among the design parameters are identified through trade-study examples.

LEARNING OUTCOMES

This course will enable you to:

- learn the principles and fundamentals of infrared optical design
- choose the proper infrared materials suite for your applications
- quickly execute flux-transfer calculations
- calibrate infrared sources and target signatures
- recognize the importance of background in thermal signatures
- have an appreciation for the capacity of infrared systems and learn the interaction of its critical components (optics, detectors, and electronics) in the production of a final infrared image
- assess the influence of noise mechanisms related to optical detection
- comprehend the fundamental response mechanisms and differences between cooled and uncooled single detectors as well as focal plane arrays (FPAs)
- comprehend the central theory behind third generation infrared imagers
- define and use common descriptors for detector and system performance (R, D*, NEP, NEI, MTF, NETD, and MRTD)
- estimate system performance given subsystem and component specifications
- apply design tradeoffs in both infrared search and track systems (IRST) and thermal-imaging systems (TIS)
- carry out the preliminary design of infrared systems for different thermal applications

INTENDED AUDIENCE

This course is directed to the practicing engineers and/or scientists who require both theoretical and effective practical technical information to design, build, and/or test infrared systems in a wide variety of thermal applications. A background at the bachelor's level in engineering is highly recommended. The participant should also have ample understanding of Fourier analysis and random processes.

INSTRUCTOR

Arnold Daniels is a senior lead engineer with extensive experience in the conceptual definition of advance infrared, optical, and electro-optical systems. His background consists of technical contributions to applications for infrared search & track, thermal imaging, and ISR systems. Other technical expertise include infrared radiometry (testing and measurements), infrared test systems (i.e., MTF, NETD, and MRTD), thermographic nondestructive testing (TNDT), optical design, precision optical alignment, stray light analysis, adaptive optics, Fourier analysis, image processing, and data acquisition systems. He earned an M.S. in Electrical Engineering from the University of Tel-Aviv and a doctorate in Electro-Optics from the School of Optics (CREOL) at the University of

Central Florida. In 1995 he received the Rudolf Kingslake medal and prize for the most noteworthy original paper to appear in SPIE's Journal of Optical Engineering. He is presently developing direct energy laser weapon systems for defense applications.

COURSE PRICE INCLUDES the *Field Guide to Infrared Systems, Detectors, and FPAs, 2nd Edition* by Arnold Daniels (SPIE, 2010) and *Infrared Detectors and Systems* (Wiley, 1996) by Eustace L. Dereniak and Glenn D. Boreman.

Uncooled Thermal Imaging Detectors and Systems

Updated in 2015

SC900

Course Level: Intermediate
CEU: 0.65 $555 Members | $650 Non-Members USD
Monday 8:30 am to 5:30 pm

The success of uncooled infrared imaging in commercial and military markets has greatly increased the number of participants in the field, and, consequently, the variety of products available and in development. The intent of this course is to provide attendees a broad view of the field as well as an in-depth look at important technologies. The course describes the fundamentals of uncooled IR imaging arrays, emphasizing resistive bolometric and ferroelectric/pyroelectric detectors, but also including a number of innovative technologies such as thermally activated cantilevers, thin films with temperature-dependent optical transmission properties, and thermal-capacitive detectors. Students will learn the fundamentals of uncooled IR sensors, how the various technologies operate, the merits and deficiencies of the different technologies, quantitative metrics for evaluating and comparing performance, and how key factors influence those metrics. The course also explores the limits of performance of uncooled IR imaging, as well as trends to be expected in future products.

LEARNING OUTCOMES

This course will enable you to:

- describe the operation of uncooled IR detectors and basic readout circuits
- evaluate performance in terms of responsivity, noise, noise equivalent temperature difference, minimum resolvable temperature, and response time
- gauge the fundamental limits to their performance, including temperature-fluctuation noise and background fluctuation noise
- compare theory with measured performance of the uncooled arrays
- evaluate practical issues and limitations of current technology
- ascertain the state of development of new IR technologies by asking the right questions
- differentiate well-developed concepts from ill-conceived notional concepts
- identify the uncooled IR technology best suited to your needs
- assess the performance potential of novel IR imaging technologies
- evaluate quantitatively the performance of a wide variety of uncooled IR detectors
- summarize construction details from the technical literature.

INTENDED AUDIENCE

This material is intended for engineers, scientists, and managers who need a background knowledge of uncooled IR technologies, for those who need to be able to evaluate those technologies for usefulness in particular applications, and for those working in the field who wish to deepen their knowledge and understanding. Anyone concerned with current and future directions in thermal imaging or involved in the development of IR detector technology or advanced uncooled IR system concepts will find this course valuable. The course has a significant mathematical content designed to illustrate the origin of the principles involved, but knowledge of the mathematics is not required to understand the concepts and results.

INSTRUCTOR

Charles Hanson has a Ph.D. in theoretical solid-state physics from Georgetown University. After retiring as CTO of L-3 Infrared Products in 2011, he has assumed a position as infrared technologies at Texas Instruments. He has held government and industrial positions in infrared imaging for 45 years. He is a past chairman of Military Sensing Symposia (MSS) Passive Sensors and is presently co-chair of the SPIE Infrared Technology and Applications conference.

COURSE PRICE INCLUDES the text *Uncooled Thermal Imaging Arrays, Systems, and Applications* (SPIE Press, 2001) by Paul Kruse.

Engineering Approach to Imaging System Design

Updated in 2015

SC713

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Monday 8:30 am to 5:30 pm

This course discusses the three popular approaches to electro-optical imaging system design: spatial resolution, sensitivity (signal-to-noise ratio), and modulation transfer function (MTF) analysis. While often evaluated individually, all three must be considered to optimize system design. Usually, the dominant MTFs in machine vision devices are image motion (including random vibration of the sensor), optics (including aberrations), and the detector. For man-in-the-loop operation, the display and the eye are of concern and, in many situations, these limit the overall system performance.

Equally important, but often neglected is sampling; an inherent feature of all electronic imaging systems. Sampling, which creates blocky images are particularly bothersome with periodic targets such as test targets and bar codes. An engineering approach is taken. This course will provide numerous practical design examples (case studies) to illustrate the interplay between subsystem MTFs, resolution, sensitivity, and sampling.

LEARNING OUTCOMES

This course will enable you to:

- use approximations; often called 'rules-of-thumb,' or 'back-of-the-envelope' analysis
- identify the subsystem components that affect resolution and sensitivity
- determine if your system is resolution or sensitivity limited
- equivalently determine if your system is detector-limited or optics-limited
- determine which subsystem limits system performance and why
- understand sampling artifacts (Nyquist frequency limit, aliasing, Moiré patterns, and variations in object edge location and width)
- use MTFs, resolution, sensitivity, and sampling concepts for system optimization
- understand the trade-off between MTF and aliasing

INTENDED AUDIENCE

The course is for managers, system designers, test engineers, machine vision specialists, and camera users who want the best performance from their systems. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference *Infrared Imaging Systems: Design, Analysis, Modeling and Testing* since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and IEEE and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Holst's Practical Guide to Electro-Optical Systems* (JCD Publishing, 2003) by Gerald C. Holst.

Testing and Evaluation of E-O Imaging Systems

Updated in 2015

SC067

Course Level: Advanced
CEU: 0.65 $595 Members | $690 Non-Members USD
Friday 8:30 am to 5:30 pm

This course describes all the quantitative and qualitative metrics that are used to characterize imaging system performance. While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). Data analysis techniques are independent of the sensor selected (i.e., wavelength independent). The difference lies in the input variable name (watts, lumens, or delta-T) and the output variable name (volts, lumens, or observer response). Slightly different test methodologies are used for visible and thermal imaging systems. Performance parameters discussed include resolution, responsivity, aperiodic transfer function, slit response function, random noise, uniformity, fixed pattern noise, modulation transfer function (MTF), contrast transfer function (CTF), minimum resolvable temperature (MRT), and the minimum resolvable contrast (MRC). The eye's spatial and temporal integration allows perception of images whose signal-to-noise ratio (SNR) is less than unity. Since all imaging system spatially sample the scene, sampling artifacts occur in all imagery and therefore affects all measurements. Sampling can significantly affect MRT and MTF tests. Low SNR and sampling effects are interactively demonstrated. This course describes the most common testing techniques. Equally important is identifying those parameters that adversely affect results.

LEARNING OUTCOMES

This course will enable you to:

- write concise test procedures with unambiguous system specifications
- identify all appropriate test parameters
- describe the radiometric relationship between delta-T and spectral radiance
- differentiate between observer variability and system response during MRC and MRT testing
- describe the difference between the CTF and the MTF
- learn about the latest MTF measurement techniques
- discern the difference between poor system performance, peculiarities of the system under test, and measurement errors
- assess how sampling affects test results
- appreciate the benefits and short comings of fully automated testing
- identify parameters that can lead to poor results.
- learn about evolving standardized testing concepts

INTENDED AUDIENCE

The course is for managers, specification writers, and test engineers involved with all phases of imaging system characterization ranging from satisfying customer requirements to ensuring that specifications are unambiguous and testable.

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Testing and Evaluation of Infrared Imaging Systems, Third Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Electro-Optical Imaging System Performance

Updated in 2015

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye's response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson's N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:

- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance
- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Infrared Radiometric Calibration

SC1109

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

This course describes the radiometric calibration techniques used for SI-traceable measurements of sources, detectors and material properties in the infrared wavelength region. The main goal is to enable understanding of infrared measurements with quantified uncertainties so that full uncertainty budgets can be established for the final quantities. Examples from NIST calibrations of sources, detectors and materials will be described.

The properties and measurements of various different blackbody and lamp sources will be discussed. Detector calibrations using both thermal and quantum detectors with monochromators and Fourier-transform spectrometers will be covered. Also, infrared reflectance measurements using Fourier-transform spectrometers will be explained. Examples of NIST-developed infrared transfer and working standard radiometers in field deployments will be utilized to illustrate the above concepts.

LEARNING OUTCOMES

This course will enable you to:

- choose the optimal sources for the measurement needs from the different sources available in the field
- list the procedures for selecting and calibrating infrared detectors and their associated uncertainties
- describe the uncertainty propagation principles in both source and detector calibrations
- utilize techniques for infrared material reflectance measurements and their uncertainty propagation
- characterize a radiation thermometer according to ASTM standards

INTENDED AUDIENCE

This course is designed for technical staff involved in radiometric calibrations of sources, detectors and radiometers.

INSTRUCTOR

Howard Yoon graduated with a B.S. Physics and Chemistry degree from Swarthmore College and earned his M.S. and Ph.D. Physics degrees from the University of Illinois at Urbana-Champaign. He has worked for Bell Communications Research and Dartmouth College. He currently serves as the US Representative to the Consultative Committee on Thermometry and is a member of the IEC TC65/SC65B/WG5 committee. While at NIST, he has received the Allen V. Astin Award and the DOC Silver Award. Currently at NIST he is a physicist working on several projects related to advancing spectroradiometry for improvements in fundamental and disseminated standards of spectral radiance, spectral irradiance, and radiance temperature.

George Eppeldauer received his M.E. and Ph.D. Electronics Engineering degrees from the Technical University of Budapest. Previously, he has worked at the Research Institute for Technical Physics at the Hungarian Academy of Sciences. He won the Best Paper Award at the NCSLI Conference in 2004, and he chairs the CIE TC2-48 Technical Committee (TC) on Spectral Responsivity Calibrations and the CIE TC2-29 TC on Detector Linearity. He is an electronics engineer with research areas in detector metrology developing transfer and working standard optical radiometers, photometers, and colorimeters and realizing detector responsivity based scales. The standards he has developed have been utilized to improve the two NIST SI units, the candela and kelvin, the illuminance responsivity scale, the tristimulus color scale, the spectral power, irradiance, and radiance responsivity reference-scales, and the spectral irradiance scale. He was one of the three pioneers who developed the SIRCUS reference responsivity-calibration facility.

Simon Kaplan received a B.A. Physics degree from Oberlin College and Ph.D. Physics degree from Cornell University. Prior to joining NIST, he has worked at the University of Maryland, College Park. He is a physicist with research interests in spectrophotometry and radiometry. He has worked on the characterization of optical materials and components in support of UV photolithography and infrared remote sensing applications. Currently he is leading the Low Background Infrared (LBIR) facility for absolute detector-based irradiance and radiance calibrations in support of missile defense as well as climate monitoring technology.

Charles Gibson is a Physicist in the Sensor Science Division at the National Institute of Standards and Technology. He earned his B.A. degree in Physics at Fisk University. His career at NIST began in 1986 where his research has focused on the measurement of ultraviolet, visible, and near infrared radiation sources. He realizes the NIST national scales and provides calibration services for spectral radiance, spectral irradiance, temperature, and heat flux. Mr. Gibson is active in several international committees for optical radiation measurement. He is a member of ASTM E20 Committee on Temperature Measurement and the ASTM E21.08 Subcommittee on Thermal Protection. He is a group-recipient of the 2008 Department of Commerce Silver Medal Award for Scientific/Engineering Achievement for advancing ultraviolet radiation measurement science for applications in materials processing, semiconductor manufacturing, and space sciences. He is also a co-recipient of the 2005 NIST Allen V. Astin Measurement Science Award for major advances in the realization and dissemination of the NIST spectral irradiance scale widely used in climate-change research.

This course has been designed to complement and build upon the content presented in SC1073, Radiometry and its Practical Applications. Attendees will benefit maximally from attending both courses.

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:

- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar

- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Infrared Optical Materials, Fabrication and Testing for the Optical Engineer

Updated in 2015

SC1136

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of infrared optical materials, fabrication and testing. This knowledge will help the optical engineer understand which optical specifications/tolerances lead to more cost effective optical components. Topics covered include infrared optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES

This course will enable you to:

- identify key mechanical, chemical and thermal properties of infrared optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
- review the basics of optical fabrication
- define meaningful surface tolerances
- communicate with optical fabricators
- design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies

INTENDED AUDIENCE

Optical engineers, lens designers, or managers who wish to learn more about how infrared optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Jessica DeGroote Nelson is the R&D manager and scientist at Optimax Systems, Inc. She specializes in optical materials and fabrication processes. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching an undergraduate course on Optical Fabrication and Testing, and has given several guest lectures on optical metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:

- present an overview and explain the "theory" of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/LADAR systems.
- evaluate a "basic" problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?
- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. "MODTRAN for Dummies"
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Multispectral and Hyperspectral Image Sensors

SC194

Course Level: Advanced
CEU: 0.35 $375 Members | $425 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:

- understand many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
- describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
- list and define the relevant radiometric radiometric quantities, concepts and phenomenology
- understand the process of translating system requirements into sensor hardware constraints and specifications
- analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
- define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
- describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
- list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
- formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
- provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 34 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 63 publications in these technical areas. He is a Fellow of the SPIE.

COURSE PRICE INCLUDES the text *CMOS/CCD Sensors and Camera Systems, 2nd edition* (SPIE Press, 2011) by Terrence Lomheim and Gerald Holst.

Predicting Target Acquisition Performance of Electro-Optical Imagers

SC181

Course Level: Advanced
CEU: 0.65 $570 Members | $665 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course describes how to predict and evaluate electro-optical (EO) imager performance. Metrics that quantify imager resolution are described. The detection, recognition, and identification tasks are discussed, and the meaning of acquisition probabilities is explained. The basic theory of operation of thermal imagers, image intensifiers, and video cameras is presented. This course describes how to quantify the resolution and noise characteristics of an EO imager. The theory and analysis of sampled imagers is emphasized. Image quality metrics are described, and the relationship between image quality and target acquisition performance is explained. The course provides a complete overview of how to analyze and evaluate the performance of EO imagers.

LEARNING OUTCOMES

This course will enable you to:

- describe what a target acquisition model does
- describe the operation of thermal sensors, video cameras and other EO imagers
- analyze the impact of sampling on targeting performance
- evaluate the targeting performance of an EO imager

INTENDED AUDIENCE

This course is intended for the design engineer or system analyst who is interested in quantifying the performance of EO imagers. Some background in linear systems analysis is helpful but not mandatory.

INSTRUCTOR

Richard Vollmerhausen started his engineering career in 1965 at Douglas Aircraft; he worked instrumentation on the S-IVB Stage of the Saturn Apollo. After two years in the army, he moved to the Naval Weapon Center at China Lake and designed infrared trackers for air-to-air missiles. In the early 1980's, he joined the army's Night Vision lab and became head of the branch developing targeting and pilotage systems for army aviation. In the late 1990's, he headed the Model Development Branch at NVL and developed the target acquisition models currently used by the army. After retirement in 2003, he consulted for government and industry. In 2011, he started graduate studies University of Delaware, receiving his PhD in EE in 2013. Dr. Vollmerhausen is currently Chief Engineer and a founding partner of St. Johns Optical Systems in Lake Mary, Florida.

COURSE PRICE INCLUDES the text *Analysis and Evaluation of Sampled Imaging Systems* (SPIE Press, 2010) by Richard H. Vollmerhausen, Ronald G. Driggers, and Don Reago.

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:

- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:

- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Introduction to Night Vision

SC1068

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 1:30 pm to 5:30 pm

Night vision devices have become ubiquitous in both commercial and military environments. From the very high end systems used for aviation, to the low-performance systems sold for outdoorsmen, these devices have changed the way their users operate at night. This course explains the basic principles behind night vision and discusses the different types of night vision devices, both "analog" and "digital". In addition to a survey of night vision devices, we also examine the inner workings of night vision systems and explain them in an easy to understand manner. We will discuss the design of night vision systems, both handheld and head mounted.

Although we will talk briefly about SWIR and thermal devices to differentiate them from night vision devices, this course is primarily aimed at visible and near infra-red (NIR) imagers. Imagery from both night vision cameras as well as thermal imagers will be presented and the differences between them will be compared/contrasted.

LEARNING OUTCOMES

This course will enable you to:
- identify the three basic components of a night vision imager: the sensor, the amplifier and the output component
- specify input optics (objective lenses) and output optics (eyepieces) for both analog and digital night vision devices
- explain the difference between VIS/NIR night vision, SWIR, MWIR and LWIR sensors as well as when each should be chosen
- differentiate the different generations of night vision goggles
- define appropriate light levels for night vision device testing
- describe new digital night vision devices and their advantages and disadvantages
- explain the important attributes of night vision systems and how they should be specified for "best value" performance
- predict night vision performance using NVESD models

INTENDED AUDIENCE

Scientists, engineers, technicians, procurement personnel or managers who wish to learn more about night vision devices. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Michael Browne is the Vice President of Product Development at SA Photonics. He has a Ph.D. in Optical Engineering from the University of Arizona's Optical Sciences Center. Mike has been involved in the design, test and measurement of night vision systems since 1986. At Kaiser Electronics, he led the design of numerous head mounted night vision systems including those for the RAH-66 Comanche helicopter and the USAF NVS program. He leads SA Photonics' efforts in the design and development of person-mounted information systems, including body-worn electronics, head-mounted displays and night vision systems. His current research includes investigations into the design of wide field of view night vision devices, binocular rivalry in head mounted displays, and smear reduction in digital displays.

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as "black boxes" and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:
- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work
- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world's leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Optical and Optomechanical Engineering

Introduction to Optical Alignment Techniques

SC010

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course discusses the equipment, techniques, tricks, and skills necessary to align optical systems and devices. You learn to identify errors in an optical system, and how to align lens systems.

LEARNING OUTCOMES

This course will enable you to:
- determine if errors in the optical system are due to misalignment errors or other factors such as fabrication, design, or mounting problems
- recognize and understand the fundamental imaging errors associated with optical systems
- diagnose (qualitatively and quantitively) what is wrong with an optical system by simply observing these fundamental imaging errors

- use the variety of tools available for aligning optical systems, and more importantly, how to "tweak" logically the adjustments on these devices so that the alignment proceeds quickly and efficiently
- align basic lens systems and telescopes
- align more complex optical systems such as those containing off-axis aspheric surfaces, and maintain alignment using automatic mounting techniques

INTENDED AUDIENCE

This course is directed toward engineers and technicians needing basic practical information and techniques to achieve alignment of simple optical systems, as well as seemingly more complicated off-axis aspheric mirrors. To benefit most from this course you will need a basic knowledge of the elementary properties of lenses and optical systems (i.e. focal lengths, f/numbers, magnification, and other imaging properties) and a working knowledge of simple interferometry. Some familiarity with the basic aberrations such as spherical aberration, coma, and astigmatism will be helpful.

INSTRUCTOR

Kenneth Castle Ph.D. is president of Ruda-Cardinal, Inc., an optical engineering consulting firm located in Tucson, Arizona. Ken has worked with Mitch Ruda, the originator of this course, for 28 years. Mitch passed away August 31, 2013, and Ruda-Cardinal is continuing the tradition of this course in his memory.

Introduction to Optomechanical Design

AVAILABLE IN ONLINE FORMAT

SC014

Course Level: Introductory
CEU: 1.3 $890 Members | $1,110 Non-Members USD
Wednesday - Thursday 8:30 am to 5:30 pm

This course will provide the training needed for the optical engineer to work with the mechanical features of optical systems. The emphasis is on providing techniques for rapid estimation of optical system performance. Subject matter includes material properties for optomechanical design, kinematic design, athermalization techniques, window design, lens and mirror mounting.

LEARNING OUTCOMES

This course will enable you to:

- select materials for use in optomechanical systems
- determine the effects of temperature changes on optical systems, and develop design solutions for those effects
- design high performance optical windows
- design low stress mounts for lenses
- select appropriate mounting techniques for mirrors and prisms
- describe different approaches to large and lightweight mirror design

INTENDED AUDIENCE

Engineers who need to solve optomechanical design problems. Optical designers will find that the course will give insight into the mechanical aspects of optical systems. The course will also interest those managing projects involving optomechanics. Short course SC690, Optical System Design: Layout Principles and Practice, or a firm understanding of its content, is required as background to this course.

INSTRUCTOR

Daniel Vukobratovich is a senior principal engineer at Raytheon. He has over 30 years of experience in optomechanics, is a founding member of the SPIE working group in optomechanics, and is fellow of SPIE. He has taught optomechanics in 11 countries, consulted with over 50 companies and written over 50 publications in optomechanics.

Structural Adhesives for Optical Bonding

SC015

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

Optomechanical systems require secure mounting of optical elements. Adhesives are commonly used, but rarely addressed in the literature. This course has compiled an overview of these adhesives, their properties, and how to test them. How to use them is addressed in detail with guidelines and examples provided. A summary of common adhesives is presented with justification for their use. Consideration and analysis of adhesive strength, reliability, and stability are included. Different design approaches to optimize the application are presented and discussed. Many examples are described as well as lessons learned from past experience. Discussions are encouraged to address current problems of course attendees.

LEARNING OUTCOMES

This course will enable you to:

- describe and classify adhesives and how they work (epoxy, urethane, silicone, acrylic, RTV, VU-cure, etc.)
- obtain guidance in: adhesive selection, surface preparation, application, and curing
- develop a basis for analysis of stress and thermal effects
- recognize contamination/outgassing and how to avoid it
- review design options
- create and use an adhesive check list

INTENDED AUDIENCE

This course is for engineers, managers, and technicians. This course provides a foundation for the correct design for successful optical mounting; an understanding of the best options to employ for each application, and the selection and approach conducive to production. A bound course outline (that is a good reference text) is provided, including summaries of popular adhesives and their properties.

INSTRUCTOR

John Daly has 35 years of experience in lasers and optomechanics. Over this period, he has worked optical bonding problems since his thesis projects, as an employee of several major corporations, and now as a consultant. His academic background in mechanical engineering and applied physics compliments this discipline. His work experience has been diverse covering areas such as: military lasers, medical lasers, spectroscopy, point and standoff detection, and E-O systems. His roles over these years have included analysis, design, development, and production. He is a SPIE member, with numerous publications, and is a committee member of the SPIE Optomechanical Engineering Program.

Design of Multiband Optical Systems

New

SC1162

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Multispectral and hyperspectral systems are designed to increase target acquisition performance as well as answer SWaP-C (size/weight/power/cost) requirements for defense and remote sensing systems. Recent developments in optical materials enable optical systems that operate over multiple infrared bands simultaneously. This course describes techniques for designing these systems using existing and new chalcoginide materials, and it provides methods for choosing material combinations, laying out systems, and predicting performance. An emphasis is placed on understanding dispersion and thermal characteristics in order to design achromatic and athermalized dual- and multi-band infrared imaging systems. Additionally, this course will touch upon recent advances in fused, layered, and gradient index infrared optics, specifically with regard to chalcoginide materials.

LEARNING OUTCOMES

This course will enable you to:

- lay out lenses using first order optical design methods
- determine a working set of optical materials based on optical and thermal characteristics
- construct glass maps for dual-band solutions
- optimize glass types using private catalog materials and optimize systems by employing user-defined merit function constraints
- describe axial and radial gradient index infrared materials and explain the advantages/disadvantages of each type

INTENDED AUDIENCE

This course is intended for optical designers and engineers wishing to expand their knowledge of infrared and multiband optics, materials, and design principles. A working understanding of optical design methods and experience with optical design software is recommended.

INSTRUCTOR

Blair Unger is Senior Optical Designer at ASE Optics. He has authored and co-authored papers and patents covering a variety of topics ranging from design of infrared chalcoginide systems to novel solar concentrators. He earned a Ph.D. in Optics at the University of Rochester, Institute of Optics. Dr. Unger is a member of both OSA and SPIE.

COURSE PRICE INCLUDES the text *Optical Design Fundamentals for Infrared Systems, Second Edition* (SPIE, 2001) by Max Riedl.

Optical Systems Engineering

SC1052

Course Level: Introductory
CEU: 0.65 $595 Members | $690 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Optical Systems Engineering emphasizes first-order, system-level estimates of optical performance. Building on the basic principles of optical design, this course uses numerous examples to illustrate the systems-engineering processes of requirements analysis, feasibility and trade studies, subsystem interfaces, error budgets, requirements flowdown and allocation, component specifications, and vendor selection. Topics covered will include an introduction to systems engineering, geometrical optics, aberrations and image quality, radiometry, optical sources, detectors and FPAs, optomechanics, and the integration of these topics for developing a complete optical system.

LEARNING OUTCOMES

This course will enable you to:

- utilize the concepts and terminology of systems engineering as applied to optical system development
- calculate geometrical-optics parameters such as image size, image location, FOV, IFOV, and ground-sample distance (GSD)
- distinguish the various types of optical aberrations; estimate blur size and blur-to-pixel ratio, and their effects on MTF, ground-resolved distance (GRD), and image quality
- quantify radiometric performance, using the concepts of optical transmission, f/#, etendue, scattering, and stray light
- compare source types and properties; estimate radiometric performance; develop source-selection tradeoffs and specifications such as output power, irradiance, radiance, uniformity, stability, and SWaP
- compare FPA and detector types and properties; predict SNR performance combining optical, source, and detector parameters; develop detector-selection tradeoffs and specifications such as sensitivity, dynamic range, uniformity, operability, and SWaP (Size, Weight, and Power)
- explain optical component specifications; estimate thermal, structural, and dynamic effects on the performance of an optical system; utilize the results of STOP (structural, thermal, and optical) analysis and error budgets

INTENDED AUDIENCE

Intended for engineers, scientists, technicians, and managers who are developing, specifying, or purchasing optical, electro-optical, and infrared systems. Prerequisites include a familiarity with Snell's law, the lens equation for simple imaging, and the concepts of wavelength and wavefronts.

INSTRUCTOR

Keith Kasunic has more than 25 years of experience developing optical, electro-optical, infrared, and laser systems. He holds a Ph.D. in Optical Sciences from the University of Arizona, an MS in Mechanical Engineering from Stanford University, and a BS in Mechanical Engineering from MIT. He has worked for or been a consultant to a number of organizations, including Lockheed Martin, Ball Aerospace, Sandia National Labs, Nortel Networks, and Bookham. He is currently the Technical Director of Optical Systems Group, LLC. He is also an Adjunct Professor at Univ. of Central Florida's CREOL – The College of Optics and Photonics, as well as an Affiliate Instructor with Georgia Tech's SENSIAC, and an Instructor for the Optical Engineering Certificate Program at Univ. of California Irvine. This course is based on his textbook Optical Systems Engineering, published by McGraw-Hill in 2011.

COURSE PRICE INCLUDES the text *Optical Systems Engineering* (McGraw-Hill/SPIE Press, 2011) by Keith Kasunic.

Radiometry and its Practical Applications

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:

- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

Infrared Radiometric Calibration

SC1109

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

This course describes the radiometric calibration techniques used for SI-traceable measurements of sources, detectors and material properties in the infrared wavelength region. The main goal is to enable understanding of infrared measurements with quantified uncertainties so that full uncertainty budgets can be established for the final quantities. Examples from NIST calibrations of sources, detectors and materials will be described.

The properties and measurements of various different blackbody and lamp sources will be discussed. Detector calibrations using both thermal and quantum detectors with monochromators and Fourier-transform spectrometers will be covered. Also, infrared reflectance measurements using Fourier-transform spectrometers will be explained. Examples of NIST-developed infrared transfer and working standard radiometers in field deployments will be utilized to illustrate the above concepts.

LEARNING OUTCOMES

This course will enable you to:

- choose the optimal sources for the measurement needs from the different sources available in the field
- list the procedures for selecting and calibrating infrared detectors and their associated uncertainties
- describe the uncertainty propagation principles in both source and detector calibrations
- utilize techniques for infrared material reflectance measurements and their uncertainty propagation
- characterize a radiation thermometer according to ASTM standards

INTENDED AUDIENCE

This course is designed for technical staff involved in radiometric calibrations of sources, detectors and radiometers.

INSTRUCTOR

Howard Yoon graduated with a B.S. Physics and Chemistry degree from Swarthmore College and earned his M.S. and Ph.D. Physics degrees from the University of Illinois at Urbana-Champaign. He has worked for Bell Communications Research and Dartmouth College. He currently serves as the US Representative to the Consultative Committee on Thermometry and is a member of the IEC TC65/SC65B/WG5 committee. While at NIST, he has received the Allen V. Astin Award and the DOC Silver Award. Currently at NIST he is a physicist working on several projects related to advancing spectroradiometry for improvements in fundamental and disseminated standards of spectral radiance, spectral irradiance, and radiance temperature.

George Eppeldauer received his M.E. and Ph.D. Electronics Engineering degrees from the Technical University of Budapest. Previously, he has worked at the Research Institute for Technical Physics at the Hungarian Academy of Sciences. He won the Best Paper Award at the NCSLI Conference in 2004, and he chairs the CIE TC2-48 Technical Committee (TC) on Spectral Responsivity Calibrations and the CIE TC2-29 TC on Detector Linearity. He is an electronics engineer with research areas in detector metrology developing transfer and working standard optical radiometers, photometers, and colorimeters and realizing detector responsivity based scales. The standards he has developed have been utilized to improve the two NIST SI units, the candela and kelvin, the illuminance responsivity scale, the tristimulus color scale, the spectral power, irradiance, and radiance responsivity reference-scales, and the spectral irradiance scale. He was one of the three pioneers who developed the SIRCUS reference responsivity-calibration facility.

Simon Kaplan received a B.A. Physics degree from Oberlin College and Ph.D. Physics degree from Cornell University. Prior to joining NIST, he has worked at the University of Maryland, College Park. He is a physicist with research interests in spectrophotometry and radiometry. He has worked on the characterization of optical materials and components in support of UV photolithography and infrared remote sensing applications. Currently he is leading the Low Background Infrared (LBIR) facility for absolute detector-based irradiance and radiance calibrations in support of missile defense as well as climate monitoring technology.

Charles Gibson is a Physicist in the Sensor Science Division at the National Institute of Standards and Technology. He earned his B.A. degree in Physics at Fisk University. His career at NIST began in 1986 where his research has focused on the measurement of ultraviolet, visible, and near infrared radiation sources. He realizes the NIST national scales and provides calibration services for spectral radiance, spectral irradiance, temperature, and heat flux. Mr. Gibson is active in several international committees for optical radiation measurement. He is a member of ASTM E20 Committee on Temperature Measurement and the ASTM E21.08 Subcommittee on Thermal Protection. He is a group-recipient of the 2008 Department of Commerce Silver Medal Award for Scientific/Engineering Achievement for advancing ultraviolet radiation measurement science for applications in materials processing, semiconductor manufacturing, and space sciences. He is also a co-recipient of the 2005 NIST Allen V. Astin Measurement Science Award for major advances in the realization and dissemination of the NIST spectral irradiance scale widely used in climate-change research.

This course has been designed to complement and build upon the content presented in SC1073, Radiometry and its Practical Applications. Attendees will benefit maximally from attending both courses.

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:
- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar
- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Infrared Optical Materials, Fabrication and Testing for the Optical Engineer

SC1136

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of infrared optical materials, fabrication and testing. This knowledge will help the optical engineer understand which optical specifications/tolerances lead to more cost effective optical components. Topics covered include infrared optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES

This course will enable you to:
- identify key mechanical, chemical and thermal properties of infrared optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
- review the basics of optical fabrication
- define meaningful surface tolerances
- communicate with optical fabricators
- design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies

INTENDED AUDIENCE

Optical engineers, lens designers, or managers who wish to learn more about how infrared optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Jessica DeGroote Nelson is the R&D manager and scientist at Optimax Systems, Inc. She specializes in optical materials and fabrication processes. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching an undergraduate course on Optical Fabrication and Testing, and has given several guest lectures on optical metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.

Basic Optics for Non-Optics Personnel

AVAILABLE IN ONLINE FORMAT

SC609

Course Level: Introductory
CEU: 0.2 $100 Members | $150 Non-Members USD
Wednesday 8:30 am to 11:00 am

This course will provide the technical manager, sales engineering, marketing staff, or other non-optics personnel with a basic, non-mathematical introduction to the terms, specifications, and concepts used in optical technology to facilitate effective communication with optics professionals on a functional level. Topics to be covered include basic concepts such as imaging, interference, diffraction, polarization and aberrations, definitions relating to color and optical quality, and an overview of the basic measures of optical performance such as MTF and wavefront error. The material will be presented with a minimal amount of math, rather emphasizing working concepts, definitions, rules of thumb, and visual interpretation of specifications. Specific applications will include defining basic imaging needs such as magnification, depth-of-field, and MTF as well as the definitions of radiometric terms.

LEARNING OUTCOMES

This course will enable you to:
- read optical system descriptions and papers
- ask the right questions about optical component performance
- describe basic optical specifications for lenses, filters, and other components
- assess differences in types of filters, mirrors and beam directing optics
- know how optics is used in our everyday lives

INTENDED AUDIENCE

This course is intended for the non-optical professional who needs to understand basic optics and interface with optics professionals.

INSTRUCTOR

Kevin Harding has been active in the optics industry for over 30 years, and has taught machine vision and optical methods for over 25 years in over 70 workshops and tutorials, including engineering workshops on machine vision, metrology, NDT, and interferometry used by vendors and system houses to train their own engineers. He has been recognized for his leadership in optics and machine vision by the Society of Manufacturing Engineers, Automated Imaging Association, and Engineering Society of Detroit. Kevin is a Fellow of SPIE and was the 2008 President of the Society.

Engineering Approach to Imaging System Design

SC713

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Monday 8:30 am to 5:30 pm

This course discusses the three popular approaches to electro-optical imaging system design: spatial resolution, sensitivity (signal-to-noise ratio), and modulation transfer function (MTF) analysis. While often evaluated individually, all three must be considered to optimize system design. Usually, the dominant MTFs in machine vision devices are image motion (including random vibration of the sensor), optics (including aberrations), and the detector. For man-in-the-loop operation, the display and the eye are of concern and, in many situations, these limit the overall system performance.

Equally important, but often neglected is sampling; an inherent feature of all electronic imaging systems. Sampling, which creates blocky images are particularly bothersome with periodic targets such as test targets and bar codes. An engineering approach is taken. This course will provide numerous practical design examples (case studies) to illustrate the interplay between subsystem MTFs, resolution, sensitivity, and sampling.

LEARNING OUTCOMES

This course will enable you to:

- use approximations; often called 'rules-of-thumb,' or 'back-of-the-envelope' analysis
- identify the subsystem components that affect resolution and sensitivity
- determine if your system is resolution or sensitivity limited
- equivalently determine if your system is detector-limited or optics-limited
- determine which subsystem limits system performance and why
- understand sampling artifacts (Nyquist frequency limit, aliasing, Moiré patterns, and variations in object edge location and width)
- use MTFs, resolution, sensitivity, and sampling concepts for system optimization
- understand the trade-off between MTF and aliasing

INTENDED AUDIENCE

The course is for managers, system designers, test engineers, machine vision specialists, and camera users who want the best performance from their systems. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference *Infrared Imaging Systems: Design, Analysis, Modeling and Testing* since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and IEEE and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Holst's Practical Guide to Electro-Optical Systems* (JCD Publishing, 2003) by Gerald C. Holst.

Imaging and Sensing Technologies

Fundamentals of Fiber Optic Sensor Design and Technology

New

SC1160

Course Level: Introductory
CEU: 0.65 $545 Members | $640 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course explains basic principles and applications of fiber optic sensor technology. A primary goal of the course is to present the underlying principals associated with the design and application of fiber optic sensor technology.

The course begins with an overview of the fundamental components associated with fiber optic sensors and how they interact to form intensity-based and interferometry-based fiber sensors. It then continues with an overview of physical fiber optic sensors starting with intensity-based sensors and continuing with those based on the Mach-Zehnder, Michelson and Sagnac interferometers. A review of fiber gratings and fiber-etalon-based sensors follows. Examples of applications are given in a wide variety of fields including aerospace and defense, civil structures, oil and gas, and composite manufacturing.

The course continues with an examination of the important emerging areas of chemical and biological fiber sensors – including spectroscopic, refractometric, and more exotic types. Applications ranging from biomedical diagnosis to environmental monitoring will be discussed.

Anyone seeking a rapid and effective introduction to the field of fiber optic sensor technology would benefit greatly from this course. It is intended to strongly complement and serve as an introduction to the *Fiber Optic Sensors and Applications Conference* associated with this Symposium.

LEARNING OUTCOMES

This course will enable you to:

- describe the fundamental components associated with most fiber optic sensors
- explain how components interact and how the performance of a fiber sensor depends on these interactions
- identify common intensity-based fiber sensors, their application areas, their advantages and limitations
- compare the relative advantages of different sensor classes (e.g., intrinsic vs. extrinsic, single-point vs. distributed; active vs. passive) and readout techniques (e.g., wavelength vs. intensity, direct vs. modulated, homodyne vs. heterodyne)
- explain the operation of the Mach-Zehnder, Michelson and Sagnac interferometers and how they are being applied in the field
- determine the strain and temperature response of fiber grating sensors
- describe how fiber grating sensors may be used to supported multi-parameter sensing, including pressure and temperature and multi-axis strain
- understand the operation and applications of evanescent-field, optrode-style, and remote-spectroscopic sensors
- explain the application and operation of fiber-etalon-based sensors
- identify classes of chemical and biological fiber sensors
- be familiar with applications of fiber sensors in medical, chemical, environmental, aerospace, defense, oil and gas, civil structure and manufacturing applications

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to design and apply fiber optic sensors to a wide range of applications. Undergraduate training in engineering or science would be of great benefit.

INSTRUCTOR

Eric Udd has been designing and developing fiber optic sensor technology since 1977, at McDonnell Douglas, Blue Road Research and as President of Columbia Gorge Research since January 2006. He has made fundamental contributions to fiber optic rotation, acoustic, pressure, strain, temperature, and moisture sensors. Mr. Udd has 48 issued patents on fiber optic technology and approximately 170 papers. He is a McDonnell Douglas, SPIE and OSA Fellow and in 2009 was awarded the Richardson Medal by OSA for this work in Fiber Optic Sensors and the field of Fiber Optic Smart Structures.

Robert Lieberman has most recently been the President and Chief Technology Officer of Intelligent Optical Systems, Inc., and serves or has served on the Boards of SPIE, Optech, OptiSense LLC, and Optical Security Sensing LLC. Dr. Lieberman's background includes a Ph.D. in physics from the University of Michigan, and a scientific and technical management career at AT&T Bell Laboratories and Physical Optics Corporation notable for inventions and ground-breaking research projects in microelectronic devices, optical biosensors, physical and chemical sensors, and sensor networks. Dr. Lieberman has written over 50 publications, holds 21 U.S. patents, has chaired numerous conferences on optical sensing, and is a Fellow of SPIE.

COURSE PRICE INCLUDES the text *Fiber Optic Sensor Field Guide* (SPIE Press, 2015), by William B. Spillman and Eric Udd.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Statistics for Imaging and Sensor Data

SC1072

Course Level: Introductory
CEU: 0.65 $575 Members | $670 Non-Members USD
Monday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

- apply the statistical methods suitable for a given context
- demonstrate the statistical significance of your results based on hypothesis testing
- construct confidence intervals for a variety of imaging applications
- fit predictive equations to your imaging data
- construct confidence and prediction intervals for a response variable as a function of predictors
- explain the basics of statistical signal processing and its relationship to linear regression models
- perform correct analysis of outliers in data
- implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics and Graduate Program Chair at the Rochester Institute of Technology. He teaches graduate and undergraduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in a prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text *Statistics for Imaging, Optics, and Photonics* (Wiley, 2011) by Peter Bajorski.

Design of Multiband Optical Systems

New

SC1162

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Multispectral and hyperspectral systems are designed to increase target acquisition performance as well as answer SWaP-C (size/weight/power/cost) requirements for defense and remote sensing systems. Recent developments in optical materials enable optical systems that operate over multiple infrared bands simultaneously. This course describes techniques for designing these systems using existing and new chalcoginide materials, and it provides methods for choosing material combinations, laying out systems, and predicting performance. An emphasis is placed on understanding dispersion and thermal characteristics in order to design achromatic and athermalized dual- and multi-band infrared imaging systems. Additionally, this course will touch upon recent advances in fused, layered, and gradient index infrared optics, specifically with regard to chalcoginide materials.

LEARNING OUTCOMES

This course will enable you to:

- lay out lenses using first order optical design methods
- determine a working set of optical materials based on optical and thermal characteristics
- construct glass maps for dual-band solutions
- optimize glass types using private catalog materials and optimize systems by employing user-defined merit function constraints
- describe axial and radial gradient index infrared materials and explain the advantages/disadvantages of each type

INTENDED AUDIENCE

This course is intended for optical designers and engineers wishing to expand their knowledge of infrared and multiband optics, materials, and design principles. A working understanding of optical design methods and experience with optical design software is recommended.

INSTRUCTOR

Blair Unger is Senior Optical Designer at ASE Optics. He has authored and co-authored papers and patents covering a variety of topics ranging from design of infrared chalcoginide systems to novel solar concentrators. He earned a Ph.D. in Optics at the University of Rochester, Institute of Optics. Dr. Unger is a member of both OSA and SPIE.

COURSE PRICE INCLUDES the text *Optical Design Fundamentals for Infrared Systems, Second Edition* (SPIE, 2001) by Max Riedl.

Radiometry and its Practical Applications

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:

- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:
- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar
- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Uncooled Thermal Imaging Detectors and Systems

SC900

Course Level: Intermediate
CEU: 0.65 $555 Members | $650 Non-Members USD
Monday 8:30 am to 5:30 pm

The success of uncooled infrared imaging in commercial and military markets has greatly increased the number of participants in the field, and, consequently, the variety of products available and in development. The intent of this course is to provide attendees a broad view of the field as well as an in-depth look at important technologies. The course describes the fundamentals of uncooled IR imaging arrays, emphasizing resistive bolometric and ferroelectric/pyroelectric detectors, but also including a number of innovative technologies such as thermally activated cantilevers, thin films with temperature-dependent optical transmission properties, and thermal-capacitive detectors. Students will learn the fundamentals of uncooled IR sensors, how the various technologies operate, the merits and deficiencies of the different technologies, quantitative metrics for evaluating and comparing performance, and how key factors influence those metrics. The course also explores the limits of performance of uncooled IR imaging, as well as trends to be expected in future products.

LEARNING OUTCOMES

This course will enable you to:
- describe the operation of uncooled IR detectors and basic readout circuits
- evaluate performance in terms of responsivity, noise, noise equivalent temperature difference, minimum resolvable temperature, and response time
- gauge the fundamental limits to their performance, including temperature-fluctuation noise and background fluctuation noise
- compare theory with measured performance of the uncooled arrays
- evaluate practical issues and limitations of current technology
- ascertain the state of development of new IR technologies by asking the right questions
- differentiate well-developed concepts from ill-conceived notional concepts
- identify the uncooled IR technology best suited to your needs
- assess the performance potential of novel IR imaging technologies
- evaluate quantitatively the performance of a wide variety of uncooled IR detectors
- summarize construction details from the technical literature.

INTENDED AUDIENCE

This material is intended for engineers, scientists, and managers who need a background knowledge of uncooled IR technologies, for those who need to be able to evaluate those technologies for usefulness in particular applications, and for those working in the field who wish to deepen their knowledge and understanding. Anyone concerned with current and future directions in thermal imaging or involved in the development of IR detector technology or advanced uncooled IR system concepts will find this course valuable. The course has a significant mathematical content designed to illustrate the origin of the principles involved, but knowledge of the mathematics is not required to understand the concepts and results.

INSTRUCTOR

Charles Hanson has a Ph.D. in theoretical solid-state physics from Georgetown University. After retiring as CTO of L-3 Infrared Products in 2011, he has assumed a position as infrared technologies at Texas Instruments. He has held government and industrial positions in infrared imaging for 45 years. He is a past chairman of Military Sensing Symposia (MSS) Passive Sensors and is presently co-chair of the SPIE Infrared Technology and Applications conference.

COURSE PRICE INCLUDES the text *Uncooled Thermal Imaging Arrays, Systems, and Applications* (SPIE Press, 2001) by Paul Kruse.

Target Detection Algorithms for Hyperspectral Imagery

SC995

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of automatic target and object detection and its applications in Hyperspectral Imagery (HSI). The primary goal of this course is to introduce the well known target detection algorithms in hyperspectral imagery. Examples of the classical target detection techniques such as spectral matched filter, subspace matched filter, adaptive matched filter, orthogonal subspace, support vector machine (SVM) and machine learning are reviewed. Construction of invariance subspaces for target and background as well as the use of regularization techniques are presented. Standard atmospheric correction and compensation techniques are reviewed. Anomaly detection techniques for HSI and dual band FLIR imagery are also discussed. Applications of HSI for detection of mines, targets, humans, chemical plumes and anomalies are reviewed.

LEARNING OUTCOMES

This course will enable you to:

- describe the fundamental concepts of target detection algorithms as applied to HSI
- learn the procedure to use the generalized maximum likelihood ratio test to design spectral detectors
- describe the fundamental differences between different detection algorithms based on their model representations
- develop statistical models as well as subspace models for HSI data
- explain the difference between anomaly detection and classification
- distinguish between linear and nonlinear approaches (SVM and Kernel learning techniques)
- develop anomaly detection techniques for different environmental scenarios
- describe linear models and unmixing techniques for abundance measures
- plot ROC curves to evaluate the performance of the algorithms

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about target detection in hyperspectral, multispectral or dual-band FLIR imagery. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a senior research scientist (ST) at US Army Research Laboratory (ARL). He is also an adjunct professor in the Electrical and Computer Engineering Department at the Johns Hopkins University. He is actively engaged in research in image processing, neural networks, automatic target recognition, and video compression and its transmission over high speed networks. He has published over 200 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing,IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions for Neural Networks. He is a Fellow of IEEE and SPIE.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:

- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Infrared Systems - Technology & Design

SC835

Course Level: Advanced
CEU: 1.3 $1,045 Members | $1,265 Non-Members USD
Monday - Tuesday 8:30 am to 5:30 pm

This course covers the range of topics necessary to understand the theoretical principles of modern infrared-technology. It combines numerous engineering disciplines necessary for the development of infrared systems. Practical engineering calculations are highlighted, with examples of trade studies illustrating the interrelationships among the various hardware characteristics.

This course is comprised of four sections:

Section 1 introduces the geometrical optics concepts including image formation, stops and pupils, thick lenses and lens combinations, image quality, and the properties of infrared materials.

Section 2 covers the essentials of radiometry necessary for the quantitative understanding of infrared signatures and flux transfer. These concepts are then developed and applied to flux-transfer calculations for blackbody, graybody, and selective radiator sources. Remote temperature calibrations and measurements are then used as an illustration of these radiometric principles.

Section 3 is devoted to fundamental background issues for optical detection-processes. It compares the characteristics of cooled and uncooled detectors with an emphasis on spectral and blackbody responsivity, detectivity (D*), as well as the noise mechanisms related to optical detection. The detector parameters and capabilities of single detectors and third generation focal plane arrays (FPAs) are analyzed.

With this acquired background, Section 4 considers the systems-design aspects of infrared imagers. The impact of scan format on signal-to-noise ratio is described, and the engineering tradeoffs inherent in the development of infrared search and track (IRST) systems are explained. Figures of merit such as MTF, NETD, and MRTD of staring arrays are examined for the performance metrics of thermal sensitivity and spatial resolution of thermal imaging systems (TIS). Contrast threshold functions based on Johnson and visible cycles (often denoted as N- and V-cycles) are specified. The interrelationships among the design parameters are identified through trade-study examples.

LEARNING OUTCOMES

This course will enable you to:

- learn the principles and fundamentals of infrared optical design
- choose the proper infrared materials suite for your applications
- quickly execute flux-transfer calculations
- calibrate infrared sources and target signatures
- recognize the importance of background in thermal signatures
- have an appreciation for the capacity of infrared systems and learn the interaction of its critical components (optics, detectors, and electronics) in the production of a final infrared image
- assess the influence of noise mechanisms related to optical detection
- comprehend the fundamental response mechanisms and differences between cooled and uncooled single detectors as well as focal plane arrays (FPAs)
- comprehend the central theory behind third generation infrared imagers
- define and use common descriptors for detector and system performance (R, D*, NEP, NEI, MTF, NETD, and MRTD)
- estimate system performance given subsystem and component specifications
- apply design tradeoffs in both infrared search and track systems (IRST) and thermal-imaging systems (TIS)
- carry out the preliminary design of infrared systems for different thermal applications

INTENDED AUDIENCE

This course is directed to the practicing engineers and/or scientists who require both theoretical and effective practical technical information to design, build, and/or test infrared systems in a wide variety of thermal applications. A background at the bachelor's level in engineering is highly recommended. The participant should also have ample understanding of Fourier analysis and random processes.

INSTRUCTOR

Arnold Daniels is a senior lead engineer with extensive experience in the conceptual definition of advance infrared, optical, and electro-optical systems. His background consists of technical contributions to applications for infrared search & track, thermal imaging, and ISR systems. Other technical expertise include infrared radiometry (testing and measurements), infrared test systems (i.e., MTF, NETD, and MRTD), thermographic nondestructive testing (TNDT), optical design, precision optical alignment, stray light analysis, adaptive optics, Fourier analysis, image processing, and data acquisition systems. He earned an M.S. in Electrical Engineering from the University of Tel-Aviv and a doctorate in Electro-Optics from the School of Optics (CREOL) at the University of Central Florida. In 1995 he received the Rudolf Kingslake medal and prize for the most noteworthy original paper to appear in SPIE's Journal of Optical Engineering. He is presently developing direct energy laser weapon systems for defense applications.

COURSE PRICE INCLUDES the *Field Guide to Infrared Systems, Detectors, and FPAs, 2nd Edition* by Arnold Daniels (SPIE, 2010) and *Infrared Detectors and Systems* (Wiley, 1996) by Eustace L. Dereniak and Glenn D. Boreman.

Electro-Optical Imaging System Performance

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye's response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson's N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:

- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance

- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Multispectral and Hyperspectral Image Sensors

SC194

Course Level: Advanced
CEU: 0.35 $375 Members | $425 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:

- understand many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
- describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
- list and define the relevant radiometric radiometric quantities, concepts and phenomenology
- understand the process of translating system requirements into sensor hardware constraints and specifications
- analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
- define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
- describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
- list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
- formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
- provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 34 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 63 publications in these technical areas. He is a Fellow of the SPIE.

COURSE PRICE INCLUDES the text *CMOS/CCD Sensors and Camera Systems, 2nd edition* (SPIE Press, 2011) by Terrence Lomheim and Gerald Holst.

Testing and Evaluation of E-O Imaging Systems

SC067

Course Level: Advanced
CEU: 0.65 $595 Members | $690 Non-Members USD
Friday 8:30 am to 5:30 pm

This course describes all the quantitative and qualitative metrics that are used to characterize imaging system performance. While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). Data analysis techniques are independent of the sensor selected (i.e., wavelength independent). The difference lies in the input variable name (watts, lumens, or delta-T) and the output variable name (volts, lumens, or observer response). Slightly different test methodologies are used for visible and thermal imaging systems. Performance parameters discussed include resolution, responsivity, aperiodic transfer function, slit response function, random noise, uniformity, fixed pattern noise, modulation transfer function (MTF), contrast transfer function (CTF), minimum resolvable temperature (MRT), and the minimum resolvable contrast (MRC). The eye's spatial and temporal integration allows perception of images whose signal-to-noise ratio (SNR) is less than unity. Since all imaging system spatially sample the scene, sampling artifacts occur in all imagery and therefore affects all measurements. Sampling can significantly affect MRT and MTF tests. Low SNR and sampling effects are interactively demonstrated. This course describes the most common testing techniques. Equally important is identifying those parameters that adversely affect results.

LEARNING OUTCOMES

This course will enable you to:

- write concise test procedures with unambiguous system specifications
- identify all appropriate test parameters
- describe the radiometric relationship between delta-T and spectral radiance
- differentiate between observer variability and system response during MRC and MRT testing
- describe the difference between the CTF and the MTF
- learn about the latest MTF measurement techniques
- discern the difference between poor system performance, peculiarities of the system under test, and measurement errors
- assess how sampling affects test results
- appreciate the benefits and short comings of fully automated testing

- identify parameters that can lead to poor results.
- learn about evolving standardized testing concepts

INTENDED AUDIENCE

The course is for managers, specification writers, and test engineers involved with all phases of imaging system characterization ranging from satisfying customer requirements to ensuring that specifications are unambiguous and testable.

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Testing and Evaluation of Infrared Imaging Systems, Third Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Engineering Approach to Imaging System Design

SC713

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Monday 8:30 am to 5:30 pm

This course discusses the three popular approaches to electro-optical imaging system design: spatial resolution, sensitivity (signal-to-noise ratio), and modulation transfer function (MTF) analysis. While often evaluated individually, all three must be considered to optimize system design. Usually, the dominant MTFs in machine vision devices are image motion (including random vibration of the sensor), optics (including aberrations), and the detector. For man-in-the-loop operation, the display and the eye are of concern and, in many situations, these limit the overall system performance.

Equally important, but often neglected is sampling; an inherent feature of all electronic imaging systems. Sampling, which creates blocky images are particularly bothersome with periodic targets such as test targets and bar codes. An engineering approach is taken. This course will provide numerous practical design examples (case studies) to illustrate the interplay between subsystem MTFs, resolution, sensitivity, and sampling.

LEARNING OUTCOMES

This course will enable you to:

- use approximations; often called ‘rules-of-thumb,’ or ‘back-of-the-envelope’ analysis
- identify the subsystem components that affect resolution and sensitivity
- determine if your system is resolution or sensitivity limited
- equivalently determine if your system is detector-limited or optics-limited
- determine which subsystem limits system performance and why
- understand sampling artifacts (Nyquist frequency limit, aliasing, Moiré patterns, and variations in object edge location and width)
- use MTFs, resolution, sensitivity, and sampling concepts for system optimization
- understand the trade-off between MTF and aliasing

INTENDED AUDIENCE

The course is for managers, system designers, test engineers, machine vision specialists, and camera users who want the best performance from their systems. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference *Infrared Imaging Systems: Design, Analysis, Modeling and Testing* since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and IEEE and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Holst’s Practical Guide to Electro-Optical Systems* (JCD Publishing, 2003) by Gerald C. Holst.

Infrared Focal Plane Arrays

SC152

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

The course presents a fundamental understanding of two-dimensional arrays applied to detecting the infrared spectrum. The physics and electronics associated with 2-D infrared detection are stressed with special emphasis on the hybrid architecture unique to two-dimensional infrared arrays.

LEARNING OUTCOMES

This course will enable you to:

- develop the building blocks of 2-D arrays
- explain charge transfer concepts of various architectures
- describe various input electronics circuits
- discuss testing techniques used in the IR for 2-D arrays
- provide an overview of current technologies
- demonstrate aliasing effects
- describe digital FPAs
- review room-temperature thermal arrays
- review uncooled photon arrays
- discuss dual band arrays
- discuss small pixel pitch devices
- review HOT devices
- compare II-VI vs. III-V devices

INTENDED AUDIENCE

This material is intended for engineers, scientists and project managers who need to learn more about two-dimensional IR arrays from a user’s point of view. It gives the student insight into the optical detection process, as well as what is available to application engineers, advantages, characteristics and performance.

INSTRUCTOR

Eustace Dereniak is a Professor of Optical Sciences and Electrical and Computer Engineering at the University of Arizona, Tucson, AZ. His research interests are in the areas of detectors for optical radiation, imaging spectrometers and imaging polarimeters instrument development. Dereniak is a co-author of several textbooks and has authored book chapters. His publications also include over 100 authored or co-authored refereed articles. He spent many years in industrial research with Raytheon, Rockwell International, and Ball Brothers Research Corporation. He has taught extensively and is a Fellow of the SPIE and OSA, and a member of the Board of Directors of SPIE.

John Hubbs is an engineer at the Infrared Radiation Effects Laboratory (IRREL). Dr. Hubbs has over 30 years of experience characterizing focal plane arrays (FPAs) in both clear and radiation environments. His research interests are in the areas of detectors for optical radiation and radiation effects on infrared focal plane arrays, which has resulted in the publication of over 75 papers. He is a Fellow of the SPIE and the Military Sensing Symposium (MSS).

Analog-to-Digital Converters for Digital ROICs

SC1076

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors. Attendees will learn how to evaluate ADC architectures using basic figures of merit for use in different sensor formats. We will cover a wide range of cutting edge architectures and see published examples without delving into transistor level theory. We will survey both academia and industrial ADC architectures. From this survey attendees will discover the industrial design evolution convergence down to a few workhorse architectures and what lessons it imparts to the image sensor community. If you are interested in the digital ROIC revolution or if you ever interface with designers or evaluate digital ROIC proposals, then you will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
- identify analog-to-digital architectures used for creating digital ROICs and image sensors
- calculate ADC architecture figures of merit important to image sensors
- evaluate ADC architecture compatibility with image sensor format and requirements
- infer the direction in which state-of-the-art digital image sensors are headed
- name the top ADC architectures used by commercial industry and explain how this knowledge benefits the image sensor industry
- stimulate your own creativity and help you develop new ideas and applications for digital ROICs and digital image sensors

INTENDED AUDIENCE

This course is intended for engineers and physicists with a background in basic electrical theory (electrical stimuli, resistors, capacitors and block diagramming) who wish to learn about analog-to-digital converter architectures and how they are applied to digital ROICs and digital image sensors. An undergraduate degree in science or engineering is assumed, and basic knowledge of electrical engineering will be particularly helpful.

INSTRUCTOR

Kenton Veeder is a ROIC design engineer, systems engineer, and part time detector physicist. He has been in the defense and commercial image sensor field for over 12 years and is the president of Senseeker Engineering Inc. in Santa Barbara, California. He has nine patents and several publications, one of which earned the MSS Detectors best paper award in 2006. While working for Raytheon he was awarded recognition as Raytheon's 'Father of the Digital Focal Plane Array' and he and his team were given the company wide 'Excellence In Technology' award. Kenton earned his M.S. in electrical engineering from the Analog-and-Mixed Signal Center at Texas A&M University. Kenton is a member of SPIE and IEEE.

Infrared Radiometric Calibration

SC1109

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

This course describes the radiometric calibration techniques used for SI-traceable measurements of sources, detectors and material properties in the infrared wavelength region. The main goal is to enable understanding of infrared measurements with quantified uncertainties so that full uncertainty budgets can be established for the final quantities. Examples from NIST calibrations of sources, detectors and materials will be described.

The properties and measurements of various different blackbody and lamp sources will be discussed. Detector calibrations using both thermal and quantum detectors with monochromators and Fourier-transform spectrometers will be covered. Also, infrared reflectance measurements using Fourier-transform spectrometers will be explained. Examples of NIST-developed infrared transfer and working standard radiometers in field deployments will be utilized to illustrate the above concepts.

LEARNING OUTCOMES

This course will enable you to:
- choose the optimal sources for the measurement needs from the different sources available in the field
- list the procedures for selecting and calibrating infrared detectors and their associated uncertainties
- describe the uncertainty propagation principles in both source and detector calibrations
- utilize techniques for infrared material reflectance measurements and their uncertainty propagation
- characterize a radiation thermometer according to ASTM standards

INTENDED AUDIENCE

This course is designed for technical staff involved in radiometric calibrations of sources, detectors and radiometers.

INSTRUCTOR

Howard Yoon graduated with a B.S. Physics and Chemistry degree from Swarthmore College and earned his M.S. and Ph.D. Physics degrees from the University of Illinois at Urbana-Champaign. He has worked for Bell Communications Research and Dartmouth College. He currently serves as the US Representative to the Consultative Committee on Thermometry and is a member of the IEC TC65/SC65B/WG5 committee. While at NIST, he has received the Allen V. Astin Award and the DOC Silver Award. Currently at NIST he is a physicist working on several projects related to advancing spectroradiometry for improvements in fundamental and disseminated standards of spectral radiance, spectral irradiance, and radiance temperature.

George Eppeldauer received his M.E. and Ph.D. Electronics Engineering degrees from the Technical University of Budapest. Previously, he has worked at the Research Institute for Technical Physics at the Hungarian Academy of Sciences. He won the Best Paper Award at the NCSLI Conference in 2004, and he chairs the CIE TC2-48 Technical Committee (TC) on Spectral Responsivity Calibrations and the CIE TC2-29 TC on Detector Linearity. He is an electronics engineer with research areas in detector metrology developing transfer and working standard optical radiometers, photometers, and colorimeters and realizing detector responsivity based scales. The standards he has developed have been utilized to improve the two NIST SI units, the candela and kelvin, the illuminance responsivity scale, the tristimulus color scale, the spectral power, irradiance, and radiance responsivity reference-scales, and the spectral irradiance scale. He was one of the three pioneers who developed the SIRCUS reference responsivity-calibration facility.

Simon Kaplan received a B.A. Physics degree from Oberlin College and Ph.D. Physics degree from Cornell University. Prior to joining NIST, he has worked at the University of Maryland, College Park. He is a physicist with research interests in spectrophotometry and radiometry. He has worked on the characterization of optical materials and components in support of UV photolithography and infrared remote sensing applications. Currently he is leading the Low Background Infrared (LBIR) facility for absolute detector-based irradiance and radiance calibrations in support of missile defense as well as climate monitoring technology.

Charles Gibson is a Physicist in the Sensor Science Division at the National Institute of Standards and Technology. He earned his B.A. degree in Physics at Fisk University. His career at NIST began in 1986 where his research has focused on the measurement of ultraviolet, visible, and near infrared radiation sources. He realizes the NIST national scales and provides calibration services for spectral radiance, spectral irradiance, temperature, and heat flux. Mr. Gibson is active in several international committees for optical radiation measurement. He is a member of ASTM E20 Committee on Temperature Measurement and the ASTM E21.08 Subcommittee on Thermal Protection. He is a group-recipient of the 2008 Department of Commerce Silver Medal Award for Scientific/Engineering Achievement for advancing ultraviolet radiation measurement science for applications in materials processing, semiconductor manufacturing, and space sciences. He is also a co-recipient of the 2005 NIST Allen V. Astin Measurement Science Award for major advances in the realization and dissemination of the NIST spectral irradiance scale widely used in climate-change research.

This course has been designed to complement and build upon the content presented in SC1073, Radiometry and its Practical Applications. Attendees will benefit maximally from attending both courses.

Infrared Optical Materials, Fabrication and Testing for the Optical Engineer

SC1136

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of infrared optical materials, fabrication and testing. This knowledge will help the optical engineer understand which optical specifications/tolerances lead to more cost effective optical components. Topics covered include infrared optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES

This course will enable you to:

- identify key mechanical, chemical and thermal properties of infrared optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
- review the basics of optical fabrication
- define meaningful surface tolerances
- communicate with optical fabricators
- design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies

INTENDED AUDIENCE

Optical engineers, lens designers, or managers who wish to learn more about how infrared optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Jessica DeGroote Nelson is the R&D manager and scientist at Optimax Systems, Inc. She specializes in optical materials and fabrication processes. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching an undergraduate course on Optical Fabrication and Testing, and has given several guest lectures on optical metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:

- present an overview and explain the “theory” of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/ evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/ LADAR systems.
- evaluate a “basic” problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?
- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. “MODTRAN for Dummies”
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Fundamentals of Electronic Image Processing

SC066

Course Level: Introductory
CEU: 0.65 $585 Members | $680 Non-Members USD
Monday 8:30 am to 5:30 pm

Many disciplines of science and manufacturing acquire and evaluate images on a routine basis. Typically these images must be processed so that important features can be measured or identified This short course introduces the fundamentals of electronic image processing to scientists and engineers who need to know how to manipulate images that have been acquired and stored within a digital computer.

LEARNING OUTCOMES

This course will enable you to:
- describe image storage, acquisition, and digitization
- become familiar with image transforms such as Fourier, Hough, Walsh, Hadamar, Discrete Cosine, and Hotelling
- explain the difference between the types of linear and non-linear filters and when to use each
- learn the difference between types of noise in the degradation of an image
- apply color image processing techniques to enhance key features in color and gray scale images
- recognize image segmentation techniques and how they are used to extract objects from an image
- explain software approaches to image processing
- demonstrate how to use the UCFImage image processing software program included with the course.

INTENDED AUDIENCE

This course will be useful to engineers and scientists who have a need to understand and use image processing techniques, but have no formal training in image processing. It will give the individual insight into a number of complex algorithms as it applies to several different applications of this very interesting and important field.

INSTRUCTOR

Arthur Weeks holds an associate professor position with the Dept. of Electrical and Computer Engineering at the Univ. of Central Florida. He recently left his position as a vice president of corporate technology to continue his research in image processing and bio-medical signal processing. He has published over 30 articles and three books in image processing.

COURSE PRICE INCLUDES the text *Fundamentals of Electronic Image Processing* (SPIE Press, 1996) by Arthur Weeks.

Defense, Homeland Security, and Law Enforcement

Applications and Performance of High Power Lasers in the Battlefield

New

SC1104

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Monday 1:30 pm to 5:30 pm

The course will provide an overview of high power lasers that can be used in the future battlefield as a part of an effective defense layer against ballistic missiles, rockets, and mortars. Various types of high power lasers, their mechanism of operation and interception, and the current technological status will be presented. We will demonstrate how a basic laser configuration can be upgraded into a high power military laser system. The advantages and disadvantages of various types of laser systems will be reviewed and future prospects of the potentially promising laser systems will be discussed.

LEARNING OUTCOMES

This course will enable you to:
- identify the various types of high power lasers that are used for military applications
- classify high power lasers according to their specific application areas and the environmental conditions in which they are best utilized
- evaluate and analyze the design considerations and performance of high power lasers
- analyze the advantages and limitations of lasers for military applications
- analyze the role of laser beams against present threats
- become familiar with the main concepts used in designing high power military lasers
- describe and estimate the operational characteristics required for effective high power laser deployment

INTENDED AUDIENCE

Laser engineers, optical engineers, laser scientists, laser system engineers, graduate students in laser physics, project officers, and anybody who wants to acquire knowledge in specific applications of high power lasers.

INSTRUCTOR

Yehoshua Kalisky is with the Chemistry Division of NRCN, Beer-Sheva, Israel. He is an SPIE Fellow, and holds several patents and numerous publications on laser physics, spectroscopy of laser materials, and various types of lasers such as gas and dye lasers, as well as diode-pumped solid state lasers.

Introduction to Night Vision

SC1068

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 1:30 pm to 5:30 pm

Night vision devices have become ubiquitous in both commercial and military environments. From the very high end systems used for aviation, to the low-performance systems sold for outdoorsmen, these devices have changed the way their users operate at night. This course explains the basic principles behind night vision and discusses the different types of night vision devices, both "analog" and "digital". In addition to a survey of night vision devices, we also examine the inner workings of night vision systems and explain them in an easy to understand manner. We will discuss the design of night vision systems, both handheld and head mounted.

Although we will talk briefly about SWIR and thermal devices to differentiate them from night vision devices, this course is primarily aimed at visible and near infra-red (NIR) imagers. Imagery from both night vision cameras as well as thermal imagers will be presented and the differences between them will be compared/contrasted.

LEARNING OUTCOMES

This course will enable you to:
- identify the three basic components of a night vision imager: the sensor, the amplifier and the output component
- specify input optics (objective lenses) and output optics (eyepieces) for both analog and digital night vision devices
- explain the difference between VIS/NIR night vision, SWIR, MWIR and LWIR sensors as well as when each should be chosen
- differentiate the different generations of night vision goggles

- define appropriate light levels for night vision device testing
- describe new digital night vision devices and their advantages and disadvantages
- explain the important attributes of night vision systems and how they should be specified for "best value" performance
- predict night vision performance using NVESD models

INTENDED AUDIENCE

Scientists, engineers, technicians, procurement personnel or managers who wish to learn more about night vision devices. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Michael Browne is the Vice President of Product Development at SA Photonics. He has a Ph.D. in Optical Engineering from the University of Arizona's Optical Sciences Center. Mike has been involved in the design, test and measurement of night vision systems since 1986. At Kaiser Electronics, he led the design of numerous head mounted night vision systems including those for the RAH-66 Comanche helicopter and the USAF NVS program. He leads SA Photonics' efforts in the design and development of person-mounted information systems, including body-worn electronics, head-mounted displays and night vision systems. His current research includes investigations into the design of wide field of view night vision devices, binocular rivalry in head mounted displays, and smear reduction in digital displays.

Design of Multiband Optical Systems

New

SC1162

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Multispectral and hyperspectral systems are designed to increase target acquisition performance as well as answer SWaP-C (size/weight/power/cost) requirements for defense and remote sensing systems. Recent developments in optical materials enable optical systems that operate over multiple infrared bands simultaneously. This course describes techniques for designing these systems using existing and new chalcoginide materials, and it provides methods for choosing material combinations, laying out systems, and predicting performance. An emphasis is placed on understanding dispersion and thermal characteristics in order to design achromatic and athermalized dual- and multi-band infrared imaging systems. Additionally, this course will touch upon recent advances in fused, layered, and gradient index infrared optics, specifically with regard to chalcoginide materials.

LEARNING OUTCOMES

This course will enable you to:
- lay out lenses using first order optical design methods
- determine a working set of optical materials based on optical and thermal characteristics
- construct glass maps for dual-band solutions
- optimize glass types using private catalog materials and optimize systems by employing user-defined merit function constraints
- describe axial and radial gradient index infrared materials and explain the advantages/disadvantages of each type

INTENDED AUDIENCE

This course is intended for optical designers and engineers wishing to expand their knowledge of infrared and multiband optics, materials, and design principles. A working understanding of optical design methods and experience with optical design software is recommended.

INSTRUCTOR

Blair Unger is Senior Optical Designer at ASE Optics. He has authored and co-authored papers and patents covering a variety of topics ranging from design of infrared chalcoginide systems to novel solar concentrators. He earned a Ph.D. in Optics at the University of Rochester, Institute of Optics. Dr. Unger is a member of both OSA and SPIE.

COURSE PRICE INCLUDES the text *Optical Design Fundamentals for Infrared Systems, Second Edition* (SPIE, 2001) by Max Riedl.

Target Detection Algorithms for Hyperspectral Imagery

SC995

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of automatic target and object detection and its applications in Hyperspectral Imagery (HSI). The primary goal of this course is to introduce the well known target detection algorithms in hyperspectral imagery. Examples of the classical target detection techniques such as spectral matched filter, subspace matched filter, adaptive matched filter, orthogonal subspace, support vector machine (SVM) and machine learning are reviewed. Construction of invariance subspaces for target and background as well as the use of regularization techniques are presented. Standard atmospheric correction and compensation techniques are reviewed. Anomaly detection techniques for HSI and dual band FLIR imagery are also discussed. Applications of HSI for detection of mines, targets, humans, chemical plumes and anomalies are reviewed.

LEARNING OUTCOMES

This course will enable you to:
- describe the fundamental concepts of target detection algorithms as applied to HSI
- learn the procedure to use the generalized maximum likelihood ratio test to design spectral detectors
- describe the fundamental differences between different detection algorithms based on their model representations
- develop statistical models as well as subspace models for HSI data
- explain the difference between anomaly detection and classification
- distinguish between linear and nonlinear approaches (SVM and Kernel learning techniques)
- develop anomaly detection techniques for different environmental scenarios
- describe linear models and unmixing techniques for abundance measures
- plot ROC curves to evaluate the performance of the algorithms

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about target detection in hyperspectral, multispectral or dual-band FLIR imagery. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a senior research scientist (ST) at US Army Research Laboratory (ARL). He is also an adjunct professor in the Electrical and Computer Engineering Department at the Johns Hopkins University. He is actively engaged in research in image processing, neural networks, automatic target recognition, and video compression and its transmission over high speed networks. He has published over 200 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing,IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions for Neural Networks. He is a Fellow of IEEE and SPIE.

Predicting Target Acquisition Performance of Electro-Optical Imagers

SC181

Course Level: Advanced
CEU: 0.65 $570 Members | $665 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course describes how to predict and evaluate electro-optical (EO) imager performance. Metrics that quantify imager resolution are described. The detection, recognition, and identification tasks are discussed, and the meaning of acquisition probabilities is explained. The basic theory of operation of thermal imagers, image intensifiers, and video cameras is presented. This course describes how to quantify the resolution and noise characteristics of an EO imager. The theory and analysis of sampled imagers is emphasized. Image quality metrics are described, and the relationship between image quality and target acquisition performance is explained. The course provides a complete overview of how to analyze and evaluate the performance of EO imagers.

LEARNING OUTCOMES

This course will enable you to:
- describe what a target acquisition model does
- describe the operation of thermal sensors, video cameras and other EO imagers
- analyze the impact of sampling on targeting performance
- evaluate the targeting performance of an EO imager

INTENDED AUDIENCE

This course is intended for the design engineer or system analyst who is interested in quantifying the performance of EO imagers. Some background in linear systems analysis is helpful but not mandatory.

INSTRUCTOR

Richard Vollmerhausen started his engineering career in 1965 at Douglas Aircraft; he worked instrumentation on the S-IVB Stage of the Saturn Apollo. After two years in the army, he moved to the Naval Weapon Center at China Lake and designed infrared trackers for air-to-air missiles. In the early 1980's, he joined the army's Night Vision lab and became head of the branch developing targeting and pilotage systems for army aviation. In the late 1990's, he headed the Model Development Branch at NVL and developed the target acquisition models currently used by the army. After retirement in 2003, he consulted for government and industry. In 2011, he started graduate studies University of Delaware, receiving his PhD in EE in 2013. Dr. Vollmerhausen is currently Chief Engineer and a founding partner of St. Johns Optical Systems in Lake Mary, Florida.

COURSE PRICE INCLUDES the text *Analysis and Evaluation of Sampled Imaging Systems* (SPIE Press, 2010) by Richard H. Vollmerhausen, Ronald G. Driggers, and Don Reago.

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:
- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar
- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:

- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and

infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:

- present an overview and explain the “theory” of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/ evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/ LADAR systems.
- evaluate a “basic” problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?
- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. “MODTRAN for Dummies”
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:

- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Electro-Optical Imaging System Performance

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye's response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson's N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:

- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance
- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Testing and Evaluation of E-O Imaging Systems

SC067

Course Level: Advanced
CEU: 0.65 $595 Members | $690 Non-Members USD
Friday 8:30 am to 5:30 pm

This course describes all the quantitative and qualitative metrics that are used to characterize imaging system performance. While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). Data analysis techniques are independent of the sensor selected (i.e., wavelength independent). The difference lies in the input variable name (watts, lumens, or delta-T) and the output variable name (volts, lumens, or observer response). Slightly different test methodologies are used for visible and thermal imaging systems. Performance parameters discussed include resolution, responsivity, aperiodic transfer function, slit response function, random noise, uniformity, fixed pattern noise, modulation transfer function (MTF), contrast transfer function (CTF), minimum resolvable temperature (MRT), and the minimum resolvable contrast (MRC). The eye's spatial and temporal integration allows perception of images whose signal-to-noise ratio (SNR) is less than unity. Since all imaging system spatially sample the scene, sampling artifacts occur in all imagery and therefore affects all measurements. Sampling can significantly affect MRT and MTF tests. Low SNR and sampling effects are interactively demonstrated. This course describes the most common testing techniques. Equally important is identifying those parameters that adversely affect results.

LEARNING OUTCOMES

This course will enable you to:

- write concise test procedures with unambiguous system specifications
- identify all appropriate test parameters
- describe the radiometric relationship between delta-T and spectral radiance
- differentiate between observer variability and system response during MRC and MRT testing
- describe the difference between the CTF and the MTF
- learn about the latest MTF measurement techniques
- discern the difference between poor system performance, peculiarities of the system under test, and measurement errors
- assess how sampling affects test results
- appreciate the benefits and short comings of fully automated testing
- identify parameters that can lead to poor results.
- learn about evolving standardized testing concepts

INTENDED AUDIENCE

The course is for managers, specification writers, and test engineers involved with all phases of imaging system characterization ranging from satisfying customer requirements to ensuring that specifications are unambiguous and testable.

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Testing and Evaluation of Infrared Imaging Systems, Third Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Radiometry and its Practical Applications

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:
- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as "black boxes" and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:
- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work
- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world's leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Sensing for Industry, Environment, and Health

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:
- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Fundamentals of Fiber Optic Sensor Design and Technology

New

SC1160

Course Level: Introductory
CEU: 0.65 $545 Members | $640 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course explains basic principles and applications of fiber optic sensor technology. A primary goal of the course is to present the underlying principals associated with the design and application of fiber optic sensor technology.

The course begins with an overview of the fundamental components associated with fiber optic sensors and how they interact to form intensity-based and interferometry-based fiber sensors. It then continues with an overview of physical fiber optic sensors starting with intensity-based sensors and continuing with those based on the Mach-Zehnder, Michelson and Sagnac interferometers. A review of fiber gratings and fiber-etalon-based sensors follows. Examples of applications are given in a wide variety of fields including aerospace and defense, civil structures, oil and gas, and composite manufacturing.

The course continues with an examination of the important emerging areas of chemical and biological fiber sensors – including spectroscopic, refractometric, and more exotic types. Applications ranging from biomedical diagnosis to environmental monitoring will be discussed.

Anyone seeking a rapid and effective introduction to the field of fiber optic sensor technology would benefit greatly from this course. It is intended to strongly complement and serve as an introduction to the *Fiber Optic Sensors and Applications Conference* associated with this Symposium.

LEARNING OUTCOMES

This course will enable you to:
- describe the fundamental components associated with most fiber optic sensors
- explain how components interact and how the performance of a fiber sensor depends on these interactions
- identify common intensity-based fiber sensors, their application areas, their advantages and limitations
- compare the relative advantages of different sensor classes (e.g., intrinsic vs. extrinsic, single-point vs. distributed; active vs. passive) and readout techniques (e.g., wavelength vs. intensity, direct vs. modulated, homodyne vs. heterodyne)
- explain the operation of the Mach-Zehnder, Michelson and Sagnac interferometers and how they are being applied in the field
- determine the strain and temperature response of fiber grating sensors
- describe how fiber grating sensors may be used to supported multi-parameter sensing, including pressure and temperature and multi-axis strain
- understand the operation and applications of evanescent-field, optrode-style, and remote-spectroscopic sensors
- explain the application and operation of fiber-etalon-based sensors
- identify classes of chemical and biological fiber sensors
- be familiar with applications of fiber sensors in medical, chemical, environmental, aerospace, defense, oil and gas, civil structure and manufacturing applications

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to design and apply fiber optic sensors to a wide range of applications. Undergraduate training in engineering or science would be of great benefit.

INSTRUCTOR

Eric Udd has been designing and developing fiber optic sensor technology since 1977, at McDonnell Douglas, Blue Road Research and as President of Columbia Gorge Research since January 2006. He has made fundamental contributions to fiber optic rotation, acoustic, pressure, strain, temperature, and moisture sensors. Mr. Udd has 48 issued patents on fiber optic technology and approximately 170 papers. He is a McDonnell Douglas, SPIE and OSA Fellow and in 2009 was awarded the Richardson Medal by OSA for this work in Fiber Optic Sensors and the field of Fiber Optic Smart Structures.

Robert Lieberman has most recently been the President and Chief Technology Officer of Intelligent Optical Systems, Inc., and serves or has served on the Boards of SPIE, Optech, OptiSense LLC, and Optical Security Sensing LLC. Dr. Lieberman's background includes a Ph.D. in physics from the University of Michigan, and a scientific and technical management career at AT&T Bell Laboratories and Physical Optics Corporation notable for inventions and ground-breaking research projects in microelectronic devices, optical biosensors, physical and chemical sensors, and sensor networks. Dr. Lieberman has written over 50 publications, holds 21 U.S. patents, has chaired numerous conferences on optical sensing, and is a Fellow of SPIE.

COURSE PRICE INCLUDES the text *Fiber Optic Sensor Field Guide* (SPIE Press, 2015), by William B. Spillman and Eric Udd.

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:
- present an overview and explain the "theory" of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/ evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/ LADAR systems.
- evaluate a "basic" problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?
- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. "MODTRAN for Dummies"
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Statistics for Imaging and Sensor Data

SC1072

Course Level: Introductory
CEU: 0.65 $575 Members | $670 Non-Members USD
Monday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

- apply the statistical methods suitable for a given context
- demonstrate the statistical significance of your results based on hypothesis testing
- construct confidence intervals for a variety of imaging applications
- fit predictive equations to your imaging data
- construct confidence and prediction intervals for a response variable as a function of predictors
- explain the basics of statistical signal processing and its relationship to linear regression models
- perform correct analysis of outliers in data
- implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics and Graduate Program Chair at the Rochester Institute of Technology. He teaches graduate and undergraduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in a prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text *Statistics for Imaging, Optics, and Photonics* (Wiley, 2011) by Peter Bajorski.

Radiometry and its Practical Applications

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:
- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

Infrared Radiometric Calibration

SC1109

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

This course describes the radiometric calibration techniques used for SI-traceable measurements of sources, detectors and material properties in the infrared wavelength region. The main goal is to enable understanding of infrared measurements with quantified uncertainties so that full uncertainty budgets can be established for the final quantities. Examples from NIST calibrations of sources, detectors and materials will be described.

The properties and measurements of various different blackbody and lamp sources will be discussed. Detector calibrations using both thermal and quantum detectors with monochromators and Fourier-transform spectrometers will be covered. Also, infrared reflectance measurements using Fourier-transform spectrometers will be explained. Examples of NIST-developed infrared transfer and working standard radiometers in field deployments will be utilized to illustrate the above concepts.

LEARNING OUTCOMES

This course will enable you to:

- choose the optimal sources for the measurement needs from the different sources available in the field
- list the procedures for selecting and calibrating infrared detectors and their associated uncertainties
- describe the uncertainty propagation principles in both source and detector calibrations
- utilize techniques for infrared material reflectance measurements and their uncertainty propagation
- characterize a radiation thermometer according to ASTM standards

INTENDED AUDIENCE

This course is designed for technical staff involved in radiometric calibrations of sources, detectors and radiometers.

INSTRUCTOR

Howard Yoon graduated with a B.S. Physics and Chemistry degree from Swarthmore College and earned his M.S. and Ph.D. Physics degrees from the University of Illinois at Urbana-Champaign. He has worked for Bell Communications Research and Dartmouth College. He currently serves as the US Representative to the Consultative Committee on Thermometry and is a member of the IEC TC65/SC65B/WG5 committee. While at NIST, he has received the Allen V. Astin Award and the DOC Silver Award. Currently at NIST he is a physicist working on several projects related to advancing spectroradiometry for improvements in fundamental and disseminated standards of spectral radiance, spectral irradiance, and radiance temperature.

George Eppeldauer received his M.E. and Ph.D. Electronics Engineering degrees from the Technical University of Budapest. Previously, he has worked at the Research Institute for Technical Physics at the Hungarian Academy of Sciences. He won the Best Paper Award at the NCSLI Conference in 2004, and he chairs the CIE TC2-48 Technical Committee (TC) on Spectral Responsivity Calibrations and the CIE TC2-29 TC on Detector Linearity. He is an electronics engineer with research areas in detector metrology developing transfer and working standard optical radiometers, photometers, and colorimeters and realizing detector responsivity based scales. The standards he has developed have been utilized to improve the two NIST SI units, the candela and kelvin, the illuminance responsivity scale, the tristimulus color scale, the spectral power, irradiance, and radiance responsivity reference-scales, and the spectral irradiance scale. He was one of the three pioneers who developed the SIRCUS reference responsivity-calibration facility.

Simon Kaplan received a B.A. Physics degree from Oberlin College and Ph.D. Physics degree from Cornell University. Prior to joining NIST, he has worked at the University of Maryland, College Park. He is a physicist with research interests in spectrophotometry and radiometry. He has worked on the characterization of optical materials and components in support of UV photolithography and infrared remote sensing applications. Currently he is leading the Low Background Infrared (LBIR) facility for absolute detector-based irradiance and radiance calibrations in support of missile defense as well as climate monitoring technology.

Charles Gibson is a Physicist in the Sensor Science Division at the National Institute of Standards and Technology. He earned his B.A. degree in Physics at Fisk University. His career at NIST began in 1986 where his research has focused on the measurement of ultraviolet, visible, and near infrared radiation sources. He realizes the NIST national scales and provides calibration services for spectral radiance, spectral irradiance, temperature, and heat flux. Mr. Gibson is active in several international committees for optical radiation measurement. He is a member of ASTM E20 Committee on Temperature Measurement and the ASTM E21.08 Subcommittee on Thermal Protection. He is a group-recipient of the 2008 Department of Commerce Silver Medal Award for Scientific/Engineering Achievement for advancing ultraviolet radiation measurement science for applications in materials processing, semiconductor manufacturing, and space sciences. He is also a co-recipient of the 2005 NIST Allen V. Astin Measurement Science Award for major advances in the realization and dissemination of the NIST spectral irradiance scale widely used in climate-change research.

This course has been designed to complement and build upon the content presented in SC1073, Radiometry and its Practical Applications. Attendees will benefit maximally from attending both courses.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:
- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Target Detection Algorithms for Hyperspectral Imagery

SC995

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of automatic target and object detection and its applications in Hyperspectral Imagery (HSI). The primary goal of this course is to introduce the well known target detection algorithms in hyperspectral imagery. Examples of the classical target detection techniques such as spectral matched filter, subspace matched filter, adaptive matched filter, orthogonal subspace, support vector machine (SVM) and machine learning are reviewed. Construction of invariance subspaces for target and background as well as the use of regularization techniques are presented. Standard atmospheric correction and compensation techniques are reviewed. Anomaly detection techniques for HSI and dual band FLIR imagery are also discussed. Applications of HSI for detection of mines, targets, humans, chemical plumes and anomalies are reviewed.

LEARNING OUTCOMES

This course will enable you to:
- describe the fundamental concepts of target detection algorithms as applied to HSI
- learn the procedure to use the generalized maximum likelihood ratio test to design spectral detectors
- describe the fundamental differences between different detection algorithms based on their model representations
- develop statistical models as well as subspace models for HSI data
- explain the difference between anomaly detection and classification
- distinguish between linear and nonlinear approaches (SVM and Kernel learning techniques)
- develop anomaly detection techniques for different environmental scenarios
- describe linear models and unmixing techniques for abundance measures
- plot ROC curves to evaluate the performance of the algorithms

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about target detection in hyperspectral, multispectral or dual-band FLIR imagery. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a senior research scientist (ST) at US Army Research Laboratory (ARL). He is also an adjunct professor in the Electrical and Computer Engineering Department at the Johns Hopkins University. He is actively engaged in research in image processing, neural networks, automatic target recognition, and video compression and its transmission over high speed networks. He has published over 200 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing,IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions for Neural Networks. He is a Fellow of IEEE and SPIE.

Infrared Optical Materials, Fabrication and Testing for the Optical Engineer

SC1136

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of infrared optical materials, fabrication and testing. This knowledge will help the optical engineer understand which optical specifications/tolerances lead to more cost effective optical components. Topics covered include infrared optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES

This course will enable you to:
- identify key mechanical, chemical and thermal properties of infrared optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
- review the basics of optical fabrication
- define meaningful surface tolerances
- communicate with optical fabricators
- design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies

INTENDED AUDIENCE

Optical engineers, lens designers, or managers who wish to learn more about how infrared optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Jessica DeGroote Nelson is the R&D manager and scientist at Optimax Systems, Inc. She specializes in optical materials and fabrication processes. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching an undergraduate course on Optical Fabrication and Testing, and has given several guest lectures on optical metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.

Multispectral and Hyperspectral Image Sensors

SC194

Course Level: Advanced
CEU: 0.35 $375 Members | $425 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:
- understand many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
- describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
- list and define the relevant radiometric radiometric quantities, concepts and phenomenology
- understand the process of translating system requirements into sensor hardware constraints and specifications
- analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
- define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
- describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
- list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
- formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
- provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 34 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 63 publications in these technical areas. He is a Fellow of the SPIE.

COURSE PRICE INCLUDES the text *CMOS/CCD Sensors and Camera Systems, 2nd edition* (SPIE Press, 2011) by Terrence Lomheim and Gerald Holst.

Engineering Approach to Imaging System Design

SC713

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Monday 8:30 am to 5:30 pm

This course discusses the three popular approaches to electro-optical imaging system design: spatial resolution, sensitivity (signal-to-noise ratio), and modulation transfer function (MTF) analysis. While often evaluated individually, all three must be considered to optimize system design. Usually, the dominant MTFs in machine vision devices are image motion (including random vibration of the sensor), optics (including aberrations), and the detector. For man-in-the-loop operation, the display and the eye are of concern and, in many situations, these limit the overall system performance.

Equally important, but often neglected is sampling; an inherent feature of all electronic imaging systems. Sampling, which creates blocky images are particularly bothersome with periodic targets such as test targets and bar codes. An engineering approach is taken. This course will provide numerous practical design examples (case studies) to illustrate the interplay between subsystem MTFs, resolution, sensitivity, and sampling.

LEARNING OUTCOMES

This course will enable you to:
- use approximations; often called ‘rules-of-thumb,’ or ‘back-of-the-envelope’ analysis
- identify the subsystem components that affect resolution and sensitivity
- determine if your system is resolution or sensitivity limited
- equivalently determine if your system is detector-limited or optics-limited
- determine which subsystem limits system performance and why
- understand sampling artifacts (Nyquist frequency limit, aliasing, Moiré patterns, and variations in object edge location and width)
- use MTFs, resolution, sensitivity, and sampling concepts for system optimization
- understand the trade-off between MTF and aliasing

INTENDED AUDIENCE

The course is for managers, system designers, test engineers, machine vision specialists, and camera users who want the best performance from their systems. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference *Infrared Imaging Systems: Design, Analysis, Modeling and Testing* since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and IEEE and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Holst’s Practical Guide to Electro-Optical Systems* (JCD Publishing, 2003) by Gerald C. Holst.

Electro-Optical Imaging System Performance

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye's response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson's N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:

- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance
- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Signal & Image Processing

Fundamentals of Electronic Image Processing

SC066

Course Level: Introductory
CEU: 0.65 $585 Members | $680 Non-Members USD
Monday 8:30 am to 5:30 pm

Many disciplines of science and manufacturing acquire and evaluate images on a routine basis. Typically these images must be processed so that important features can be measured or identified This short course introduces the fundamentals of electronic image processing to scientists and engineers who need to know how to manipulate images that have been acquired and stored within a digital computer.

LEARNING OUTCOMES

This course will enable you to:

- describe image storage, acquisition, and digitization
- become familiar with image transforms such as Fourier, Hough, Walsh, Hadamar, Discrete Cosine, and Hotelling
- explain the difference between the types of linear and non-linear filters and when to use each
- learn the difference between types of noise in the degradation of an image
- apply color image processing techniques to enhance key features in color and gray scale images
- recognize image segmentation techniques and how they are used to extract objects from an image
- explain software approaches to image processing
- demonstrate how to use the UCFImage image processing software program included with the course.

INTENDED AUDIENCE

This course will be useful to engineers and scientists who have a need to understand and use image processing techniques, but have no formal training in image processing. It will give the individual insight into a number of complex algorithms as it applies to several different applications of this very interesting and important field.

INSTRUCTOR

Arthur Weeks holds an associate professor position with the Dept. of Electrical and Computer Engineering at the Univ. of Central Florida. He recently left his position as a vice president of corporate technology to continue his research in image processing and bio-medical signal processing. He has published over 30 articles and three books in image processing.

COURSE PRICE INCLUDES the text *Fundamentals of Electronic Image Processing* (SPIE Press, 1996) by Arthur Weeks.

Statistics for Imaging and Sensor Data

SC1072

Course Level: Introductory
CEU: 0.65 $575 Members | $670 Non-Members USD
Monday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

- apply the statistical methods suitable for a given context
- demonstrate the statistical significance of your results based on hypothesis testing
- construct confidence intervals for a variety of imaging applications
- fit predictive equations to your imaging data
- construct confidence and prediction intervals for a response variable as a function of predictors
- explain the basics of statistical signal processing and its relationship to linear regression models

- perform correct analysis of outliers in data
- implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics and Graduate Program Chair at the Rochester Institute of Technology. He teaches graduate and undergraduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in a prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text *Statistics for Imaging, Optics, and Photonics* (Wiley, 2011) by Peter Bajorski.

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:
- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:
- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Target Detection Algorithms for Hyperspectral Imagery

SC995

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of automatic target and object detection and its applications in Hyperspectral Imagery (HSI). The primary goal of this course is to introduce the well known target detection algorithms in hyperspectral imagery. Examples of the classical target detection techniques such as spectral matched filter, subspace matched filter, adaptive matched filter, orthogonal subspace, support vector machine (SVM) and machine learning are reviewed. Construction of invariance subspaces for target and background as well as the use of regularization techniques are presented. Standard atmospheric correction and compensation techniques are reviewed. Anomaly detection techniques for HSI and dual band FLIR imagery are also discussed. Applications of HSI for detection of mines, targets, humans, chemical plumes and anomalies are reviewed.

LEARNING OUTCOMES

This course will enable you to:
- describe the fundamental concepts of target detection algorithms as applied to HSI
- learn the procedure to use the generalized maximum likelihood ratio test to design spectral detectors
- describe the fundamental differences between different detection algorithms based on their model representations
- develop statistical models as well as subspace models for HSI data
- explain the difference between anomaly detection and classification
- distinguish between linear and nonlinear approaches (SVM and Kernel learning techniques)
- develop anomaly detection techniques for different environmental scenarios
- describe linear models and unmixing techniques for abundance measures
- plot ROC curves to evaluate the performance of the algorithms

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about target detection in hyperspectral, multispectral or dual-band FLIR imagery. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a senior research scientist (ST) at US Army Research Laboratory (ARL). He is also an adjunct professor in the Electrical and Computer Engineering Department at the Johns Hopkins University. He is actively engaged in research in image processing, neural networks, automatic target recognition, and video compression and its transmission over high speed networks. He has published over 200 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing,IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions for Neural Networks. He is a Fellow of IEEE and SPIE.

Analog-to-Digital Converters for Digital ROICs

SC1076

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors. Attendees will learn how to evaluate ADC architectures using basic figures of merit for use in different sensor formats. We will cover a wide range of cutting edge architectures and see published examples without delving into transistor level theory. We will survey both academia and industrial ADC architectures. From this survey attendees will discover the industrial design evolution convergence down to a few workhorse architectures and what lessons it imparts to the image sensor community. If you are interested in the digital ROIC revolution or if you ever interface with designers or evaluate digital ROIC proposals, then you will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
- identify analog-to-digital architectures used for creating digital ROICs and image sensors
- calculate ADC architecture figures of merit important to image sensors
- evaluate ADC architecture compatibility with image sensor format and requirements
- infer the direction in which state-of-the-art digital image sensors are headed
- name the top ADC architectures used by commercial industry and explain how this knowledge benefits the image sensor industry
- stimulate your own creativity and help you develop new ideas and applications for digital ROICs and digital image sensors

INTENDED AUDIENCE

This course is intended for engineers and physicists with a background in basic electrical theory (electrical stimuli, resistors, capacitors and block diagramming) who wish to learn about analog-to-digital converter architectures and how they are applied to digital ROICs and digital image sensors. An undergraduate degree in science or engineering is assumed, and basic knowledge of electrical engineering will be particularly helpful.

INSTRUCTOR

Kenton Veeder is a ROIC design engineer, systems engineer, and part time detector physicist. He has been in the defense and commercial image sensor field for over 12 years and is the president of Senseeker Engineering Inc. in Santa Barbara, California. He has nine patents and several publications, one of which earned the MSS Detectors best paper award in 2006. While working for Raytheon he was awarded recognition as Raytheon's 'Father of the Digital Focal Plane Array' and he and his team were given the company wide 'Excellence In Technology' award. Kenton earned his M.S. in electrical engineering from the Analog-and-Mixed Signal Center at Texas A&M University. Kenton is a member of SPIE and IEEE.

Emerging Technologies

Analog-to-Digital Converters for Digital ROICs

SC1076

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors. Attendees will learn how to evaluate ADC architectures using basic figures of merit for use in different sensor formats. We will cover a wide range of cutting edge architectures and see published examples without delving into transistor level theory. We will survey both academia and industrial ADC architectures. From this survey attendees will discover the industrial design evolution convergence down to a few workhorse architectures and what lessons it imparts to the image sensor community. If you are interested in the digital ROIC revolution or if you ever interface with designers or evaluate digital ROIC proposals, then you will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
- identify analog-to-digital architectures used for creating digital ROICs and image sensors
- calculate ADC architecture figures of merit important to image sensors
- evaluate ADC architecture compatibility with image sensor format and requirements
- infer the direction in which state-of-the-art digital image sensors are headed
- name the top ADC architectures used by commercial industry and explain how this knowledge benefits the image sensor industry
- stimulate your own creativity and help you develop new ideas and applications for digital ROICs and digital image sensors

INTENDED AUDIENCE

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INSTRUCTOR

Kenton Veeder is a ROIC design engineer, systems engineer, and part time detector physicist. He has been in the defense and commercial image sensor field for over 12 years and is the president of Senseeker Engineering Inc. in Santa Barbara, California. He has nine patents and several publications, one of which earned the MSS Detectors best paper award in 2006. While working for Raytheon he was awarded recognition as Raytheon's 'Father of the Digital Focal Plane Array' and he and his team were given the company wide 'Excellence In Technology' award. Kenton earned his M.S. in electrical engineering from the Analog-and-Mixed Signal Center at Texas A&M University. Kenton is a member of SPIE and IEEE.

Intelligence, Surveillance, and Reconnaissance

Testing and Evaluation of E-O Imaging Systems

SC067

Course Level: Advanced
CEU: 0.65 $595 Members | $690 Non-Members USD
Friday 8:30 am to 5:30 pm

This course describes all the quantitative and qualitative metrics that are used to characterize imaging system performance. While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). Data analysis techniques are independent of the sensor selected (i.e., wavelength independent). The difference lies in the input variable name (watts, lumens, or delta-T) and the output variable name (volts, lumens, or observer response). Slightly different test methodologies are used for visible and thermal imaging systems. Performance parameters discussed include resolution, responsivity, aperiodic transfer function, slit response function, random noise, uniformity, fixed pattern noise, modulation transfer function (MTF), contrast transfer function (CTF), minimum resolvable temperature (MRT), and the minimum resolvable contrast (MRC). The eye's spatial and temporal integration allows perception of images whose signal-to-noise ratio (SNR) is less than unity. Since all imaging system spatially sample the scene, sampling artifacts occur in all imagery and therefore affects all measurements. Sampling can significantly affect MRT and MTF tests. Low SNR and sampling effects are interactively demonstrated. This course describes the most common testing techniques. Equally important is identifying those parameters that adversely affect results.

LEARNING OUTCOMES

This course will enable you to:
- write concise test procedures with unambiguous system specifications
- identify all appropriate test parameters
- describe the radiometric relationship between delta-T and spectral radiance
- differentiate between observer variability and system response during MRC and MRT testing
- describe the difference between the CTF and the MTF
- learn about the latest MTF measurement techniques
- discern the difference between poor system performance, peculiarities of the system under test, and measurement errors
- assess how sampling affects test results
- appreciate the benefits and short comings of fully automated testing
- identify parameters that can lead to poor results.
- learn about evolving standardized testing concepts

INTENDED AUDIENCE

The course is for managers, specification writers, and test engineers involved with all phases of imaging system characterization ranging from satisfying customer requirements to ensuring that specifications are unambiguous and testable.

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Testing and Evaluation of Infrared Imaging Systems, Third Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Radiometry and its Practical Applications

SC1073

Course Level: Introductory
CEU: 0.65 $590 Members | $685 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course presents the basic quantities and units of radiometry and the propagation principles enabling calculation of flux transfer. It introduces sources, blackbody radiation laws, and optical material properties including emission, reflection, transmission, and absorption. It surveys optical radiation detectors and radiometric calibration configurations, and presents the Equation of Radiative Transfer and its simplifications. The problem-solving section of the course presents applications in MRTD testing, hyperspectral imaging, UAV sensor requirements, infrared reflectance analysis, and calibration.

LEARNING OUTCOMES

This course will enable you to:

- master the basics of radiometry and their systems of terminology and units
- master key radiometric laws and approximations
- describe the characterization of optical properties of surfaces, materials, and objects
- gain insight into basic properties of optical detectors and radiometric calibration
- identify approaches to problem-solving based on source and geometry considerations
- apply radiometric concepts to problems in areas including MRTD testing, hyperspectral imaging, and UAV sensors

INTENDED AUDIENCE

This course is designed for engineers and scientists dealing with electromagnetic radiation who need to quantify this radiation using international standard units and terminology. It is aimed at technologists seeking to gain familiarity with radiometric concepts and practical examples that they can apply to their own work.

INSTRUCTOR

Barbara Grant , SPIE Senior Member, has more than 30 years' engineering experience and holds an M. S. in Optical Sciences from the University of Arizona, where her thesis work was in remote sensing. She is the author of [i]Field Guide to Radiometry[/i] (2011) and co-author of [i]The Art of Radiometry[/i] (2009), both published by SPIE Press, and she is working on a book on UAV imaging sensors. Ms. Grant has taught radiometry and allied subjects for SPIE and other educational, governmental, and corporate organizations since 2009. Her consultancy, Lines and Lights Technology, has been in business since 1994 and she has addressed radiometric and systems problems throughout the spectrum from UV to IR.

COURSE PRICE INCLUDES the texts *The Art of Radiometry* (SPIE Press, 2009) by James M. Palmer and Barbara G. Grant, and the *Field Guide to Radiometry* (SPIE Press, 2011) by Barbara G. Grant .

3D Imaging Laser Radar

SC1103

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course will explain the basic principles of operation and the fundamental theoretical basis of 3D imaging laser radar systems. An analytical approach to evaluation of system performance will be presented. The design and applications of 3D imaging laser radars which employ staring arrays and flying spot scanned architectures; linear, Geiger mode and heterodyne detection; pulse, amplitude, frequency and hybrid modulation formats; and advanced system architectures will be discussed. Optimization strategies and trade space boundaries will be described. Major system components will be identified and effects of the limitations of current component performance will be identified. These limitations will form the basis of a discussion of current research objectives.

LEARNING OUTCOMES

This course will enable you to:

- identify the major elements of 3D imaging laser radar systems
- list important applications of laser radar
- predict the performance of real or conceptual 3D imaging laser radar systems
- estimate the effect of environmental factors on system performance and image quality
- estimate the effect of improved component performance on overall system performance and image quality
- formulate system level designs for common applications
- compare the 3D imaging laser radar approaches for selected applications
- identify test requirements and strategies for 3D imaging laser radar calibration and test

INTENDED AUDIENCE

Engineers, managers, scientists, and students who want to become familiar with basic principles and applications of 3D imaging laser radars or who want to be able to evaluate the performance of 3D laser radar systems.

INSTRUCTOR

Gary Kamerman is the Chief Scientist at FastMetrix, Inc. He is a Fellow of the International Society for Optical Engineering, the author of "Laser Radar" in the Infrared and Electro-Optical Handbook, and the editor of the SPIE Milestone series Selected Papers on Laser Radar as well as more than 30 other volumes. He has designed, built and tested laser radars and coherent optical systems for over 30 years. He is a technical advisor to the United States Department of Defense, National Aviation and Space Administration, and major international corporations.

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:

- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar
- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Design of Multiband Optical Systems

New

SC1162

Course Level: Intermediate
CEU: 0.65 $565 Members | $660 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Multispectral and hyperspectral systems are designed to increase target acquisition performance as well as answer SWaP-C (size/weight/power/cost) requirements for defense and remote sensing systems. Recent developments in optical materials enable optical systems that operate over multiple infrared bands simultaneously. This course describes techniques for designing these systems using existing and new chalcoginide materials, and it provides methods for choosing material combinations, laying out systems, and predicting performance. An emphasis is placed on understanding dispersion and thermal characteristics in order to design achromatic and athermalized dual- and multi-band infrared imaging systems. Additionally, this course will touch upon recent advances in fused, layered, and gradient index infrared optics, specifically with regard to chalcoginide materials.

LEARNING OUTCOMES

This course will enable you to:

- lay out lenses using first order optical design methods
- determine a working set of optical materials based on optical and thermal characteristics
- construct glass maps for dual-band solutions
- optimize glass types using private catalog materials and optimize systems by employing user-defined merit function constraints
- describe axial and radial gradient index infrared materials and explain the advantages/disadvantages of each type

INTENDED AUDIENCE

This course is intended for optical designers and engineers wishing to expand their knowledge of infrared and multiband optics, materials, and design principles. A working understanding of optical design methods and experience with optical design software is recommended.

INSTRUCTOR

Blair Unger is Senior Optical Designer at ASE Optics. He has authored and co-authored papers and patents covering a variety of topics ranging from design of infrared chalcoginide systems to novel solar concentrators. He earned a Ph.D. in Optics at the University of Rochester, Institute of Optics. Dr. Unger is a member of both OSA and SPIE.

COURSE PRICE INCLUDES the text *Optical Design Fundamentals for Infrared Systems, Second Edition* (SPIE, 2001) by Max Riedl.

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:

- present an overview and explain the "theory" of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/ evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/ LADAR systems.
- evaluate a "basic" problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?
- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. "MODTRAN for Dummies"
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:

- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Electro-Optical Imaging System Performance

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye's response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson's N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:

- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance
- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Predicting Target Acquisition Performance of Electro-Optical Imagers

SC181

Course Level: Advanced
CEU: 0.65 $570 Members | $665 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course describes how to predict and evaluate electro-optical (EO) imager performance. Metrics that quantify imager resolution are described. The detection, recognition, and identification tasks are discussed, and the meaning of acquisition probabilities is explained. The basic theory of operation of thermal imagers, image intensifiers, and video cameras is presented. This course describes how to quantify the resolution and noise characteristics of an EO imager. The theory and analysis of sampled imagers is emphasized. Image quality metrics are described, and the relationship between image quality and target acquisition performance is explained. The course provides a complete overview of how to analyze and evaluate the performance of EO imagers.

LEARNING OUTCOMES

This course will enable you to:

- describe what a target acquisition model does
- describe the operation of thermal sensors, video cameras and other EO imagers
- analyze the impact of sampling on targeting performance
- evaluate the targeting performance of an EO imager

INTENDED AUDIENCE

This course is intended for the design engineer or system analyst who is interested in quantifying the performance of EO imagers. Some background in linear systems analysis is helpful but not mandatory.

INSTRUCTOR

Richard Vollmerhausen started his engineering career in 1965 at Douglas Aircraft; he worked instrumentation on the S-IVB Stage of the Saturn Apollo. After two years in the army, he moved to the Naval Weapon Center at China Lake and designed infrared trackers for air-to-air missiles. In the early 1980's, he joined the army's Night Vision lab and became head of the branch developing targeting and pilotage systems for army aviation. In the late 1990's, he headed the Model Development Branch at NVL and developed the target acquisition models currently used by the army. After retirement in 2003, he consulted for government and industry. In 2011, he started graduate studies University of Delaware, receiving his PhD in EE in 2013. Dr. Vollmerhausen is currently Chief Engineer and a founding partner of St. Johns Optical Systems in Lake Mary, Florida.

COURSE PRICE INCLUDES the text *Analysis and Evaluation of Sampled Imaging Systems* (SPIE Press, 2010) by Richard H. Vollmerhausen, Ronald G. Driggers, and Don Reago.

Multispectral and Hyperspectral Image Sensors

SC194

Course Level: Advanced
CEU: 0.35 $375 Members | $425 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:

- understand many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
- describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
- list and define the relevant radiometric radiometric quantities, concepts and phenomenology
- understand the process of translating system requirements into sensor hardware constraints and specifications
- analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
- define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
- describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
- list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
- formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
- provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 34 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 63 publications in these technical areas. He is a Fellow of the SPIE.

COURSE PRICE INCLUDES the text *CMOS/CCD Sensors and Camera Systems, 2nd edition* (SPIE Press, 2011) by Terrence Lomheim and Gerald Holst.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as "black boxes" and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:

- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work

- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world's leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Precision Stabilized Pointing and Tracking Systems

SC160

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course provides a practical description of the design, analysis, integration, and evaluation processes associated with development of precision stabilization, pointing and tracking systems. Major topics include stabilized platform technology, electro-mechanical system configuration and analysis, and typical pointing and tracking system architectures.

LEARNING OUTCOMES

This course will enable you to:

- acquire the terminology of stabilization, pointing, and tracking systems and understand the common system architectures and operation
- define typical electro-mechanical configurations and key sub-systems and components used in precision stabilization and laser pointing systems
- describe the primary systems engineering tradeoffs and decisions that are required to configure and design stabilization, pointing and tracking systems
- distinguish the performance capabilities of specific design configurations

INTENDED AUDIENCE

This material is designed for engineers and managers responsible for design, analysis, development, or test of electro-optical stabilization, pointing and tracking systems or components. A minimum BS degree in an engineering discipline and familiarity with basic control systems is recommended.

INSTRUCTOR

James Hilkert is president of Alpha-Theta Technologies, an engineering consulting firm specializing in precision pointing, tracking and stabilization applications for clients such as Raytheon, General Dynamics, Northrop Grumman, DRS, Atlantic Positioning and the U.S. Navy. Prior to founding Alpha-Theta Technologies in 1994, he spent 20 years at Texas Instruments Defense Systems (now Raytheon) where he designed inertial tracking and pointing systems for a variety of military applications and later managed the Control Systems Technology Center. He received the Dr. Engineering degree from Southern Methodist University and MSME and BSME degrees from Mississippi State University, is a member of ASME, AIAA and SPIE, and lectures on control systems at The University of Texas at Dallas.

Laser Sensors and Systems

Laser Systems Engineering

New

SC1144

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

While there are a number of courses on laser design, this course emphasizes a systems-level overview of the design and engineering of systems which incorporate lasers. Starting with a summary of the various types of lasers and their selection, it reviews common laser specifications (peak power, spatial coherence, etc.), Gaussian beam characteristics and propagation, laser system optics, beam control and scanning, radiometry and power budgets, detectors specific to laser systems, and the integration of these topics for developing a complete laser system. The emphasis is on real-world design problems, as well as the commercial off-the-shelf (COTS) components used to solve them.

LEARNING OUTCOMES

This course will enable you to:

- describe laser types, properties, and selection, including semiconductor, solid-state, fiber, and gas lasers
- identify laser specifications such as average power, peak power, linewidth, pulse repetition frequency, etc. that are unique to specific applications such as manufacturing, biomedical systems, laser radar, laser communications, laser displays, and directed energy
- quantify Gaussian beam characteristics, propagation, and imaging; compare beam quality metrics [M2, beam-parameter product (BPP), and Strehl ratio]
- select laser system optics (windows, focusing lenses, beam expanders, collimators, beam shapers and homogenizers) and identify critical specifications for their use, including beam truncation, aberrations, surface figure, surface roughness, surface quality, material absorption, backreflections, coatings, and laser damage threshold (LDT)
- distinguish between hardware elements available for beam control, including galvonometers, polygon scanners, MEMs scanners, and f-theta lenses
- develop power budgets and radiometric estimates of performance for point and extended objects; estimate signal-to-noise ratio (SNR) for active imaging, laser ranging, and biomedical systems
- select detectors appropriate for laser systems, including PIN photodiodes, avalanche photodiodes (APDs), and photomultiplier tubes (PMTs); estimate the performance limitations of noise sources (detector, speckle, etc.) and their effects on sensitivity and SNR

INTENDED AUDIENCE

Intended for engineers (laser, systems, optical, mechanical, and electrical), scientists, technicians, and managers who are developing, specifying, or purchasing laser systems.

INSTRUCTOR

Keith Kasunic has more than 25 years of experience developing optical, electro-optical, infrared, and laser systems. He holds a Ph.D. in Optical Sciences from the University of Arizona, an MS in Mechanical Engineering from Stanford University, and a BS in Mechanical Engineering from MIT. He has worked for or been a consultant to a number of organizations, including Lockheed Martin, Ball Aerospace, Sandia National Labs, Nortel Networks, and Bookham; he is currently the Technical Director of Optical Systems Group, LLC. He is also the author of two textbooks [Optical Systems Engineering (McGraw-Hill, 2011) and Optomechanical Systems Engineering (John Wiley, 2014)], an Adjunct Professor at Univ. of Central Florida's CREOL, an Affiliate Instructor with Georgia Tech's SENSIAC, and an Instructor for the Optical Engineering Certificate Program at Univ. of California – Irvine.

Applications and Performance of High Power Lasers in the Battlefield

New

SC1104

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Monday 1:30 pm to 5:30 pm

The course will provide an overview of high power lasers that can be used in the future battlefield as a part of an effective defense layer against ballistic missiles, rockets, and mortars. Various types of high power lasers, their mechanism of operation and interception, and the current technological status will be presented. We will demonstrate how a basic laser configuration can be upgraded into a high power military laser system. The advantages and disadvantages of various types of laser systems will be reviewed and future prospects of the potentially promising laser systems will be discussed.

LEARNING OUTCOMES

This course will enable you to:

- identify the various types of high power lasers that are used for military applications
- classify high power lasers according to their specific application areas and the environmental conditions in which they are best utilized
- evaluate and analyze the design considerations and performance of high power lasers
- analyze the advantages and limitations of lasers for military applications
- analyze the role of laser beams against present threats
- become familiar with the main concepts used in designing high power military lasers
- describe and estimate the operational characteristics required for effective high power laser deployment

INTENDED AUDIENCE

Laser engineers, optical engineers, laser scientists, laser system engineers, graduate students in laser physics, project officers, and anybody who wants to acquire knowledge in specific applications of high power lasers.

INSTRUCTOR

Yehoshua Kalisky is with the Chemistry Division of NRCN, Beer-Sheva, Israel. He is an SPIE Fellow, and holds several patents and numerous publications on laser physics, spectroscopy of laser materials, and various types of lasers such as gas and dye lasers, as well as diode-pumped solid state lasers.

3D Imaging Laser Radar

SC1103

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course will explain the basic principles of operation and the fundamental theoretical basis of 3D imaging laser radar systems. An analytical approach to evaluation of system performance will be presented. The design and applications of 3D imaging laser radars which employ staring arrays and flying spot scanned architectures; linear, Geiger mode and heterodyne detection; pulse, amplitude, frequency and hybrid modulation formats; and advanced system architectures will be discussed. Optimization strategies and trade space boundaries will be described. Major system components will be identified and effects of the limitations of current component performance will be identified. These limitations will form the basis of a discussion of current research objectives.

LEARNING OUTCOMES

This course will enable you to:

- identify the major elements of 3D imaging laser radar systems
- list important applications of laser radar
- predict the performance of real or conceptual 3D imaging laser radar systems
- estimate the effect of environmental factors on system performance and image quality
- estimate the effect of improved component performance on overall system performance and image quality
- formulate system level designs for common applications
- compare the 3D imaging laser radar approaches for selected applications
- identify test requirements and strategies for 3D imaging laser radar calibration and test

INTENDED AUDIENCE

Engineers, managers, scientists, and students who want to become familiar with basic principles and applications of 3D imaging laser radars or who want to be able to evaluate the performance of 3D laser radar systems.

INSTRUCTOR

Gary Kamerman is the Chief Scientist at FastMetrix, Inc. He is a Fellow of the International Society for Optical Engineering, the author of "Laser Radar" in the Infrared and Electro-Optical Handbook, and the editor of the SPIE Milestone series Selected Papers on Laser Radar as well as more than 30 other volumes. He has designed, built and tested laser radars and coherent optical systems for over 30 years. He is a technical advisor to the United States Department of Defense, National Aviation and Space Administration, and major international corporations.

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as "black boxes" and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:
- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work
- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world's leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Introduction to Electro-Optical Systems Design

SC1112

Course Level: Intermediate
CEU: 0.65 $580 Members | $675 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Using communication theory, this full-day course explains the universal principles underlying a diverse range of electro-optical systems. From visible / infra-red imaging, to free space optical communications and laser remote sensing, the course relates key concepts in science and systems engineering to practical systems issues. To provide realistic understanding of the concepts presented, many real-world examples are included.

This course summarizes laser propagation fundamentals, coherent and incoherent optical system characterization, the effects of optical turbulence and particulate scattering on propagating laser beams, atmospheric and submarine laser communication systems concepts, and laser radar and optical imaging basics. Also included are discussions of adaptive optics, adaptive image processing, statistical hypothesis testing, and their effect on system performance.

LEARNING OUTCOMES

This course will enable you to:
- perform Fourier and Geometric Optics Analyses of electro-optical systems
- estimate detector noise statistics, detector performance, and signal-to-noise ratio
- perform first order image processing, including statistical image enhancements of incoherent images
- calculate contrast, irradiance and radiance created by the propagation of light in particulate environments
- calculate the system link budgets for laser systems, including synthetic aperture ladar
- perform statistical hypothesis testing, which includes how to calculate logarithmic likelihood ratio tests, test statistics, and probabilities of false alarm and detection
- assess and understand real-world Adaptive Optical system performance

INTENDED AUDIENCE

This course is intended for scientists, technical managers and design engineers who are interested in understanding first-order electro-optical system design and the effects that limit system performance.

INSTRUCTOR

Larry Stotts is a consultant and was the Deputy Office Director in the Strategic Technology Office of the Defense Advanced Research Projects Agency. He earned his Ph.D. in Electrical Engineering (Communications Systems) at the University of California at San Diego. He has published over 102 technical reports and journal articles and 2 co-authored books. Recognition of his work includes a Department of Defense Medal for Distinguished Civilian Service; two Secretary of Defense Medal for Meritorious Civilian Service Awards; two DARPA Technical Achievement Awards; The Technical Cooperation Program Technical Achievement Award, and the Naval Ocean Systems Center Technical Director's Award. Dr. Stotts is a Life Fellow of the SPIE, Fellow of the IEEE and a Senior Member and Fellow of OSA.

COURSE PRICE INCLUDES the text *Fundamentals of Electro-Optic Systems Design: Communications, Lidar and Imaging* by S. Karp and L. B. Stotts (Cambridge Press, 2013).

Atmospheric Codes (MODTRAN, FASCODE, and HITRAN) for Sensor Development and Evaluation

SC1137

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Passive and active sensors are developed for target acquisition and spectroscopic analysis ranging from the ultraviolet through the microwave region. Accurate atmospheric absorption and emission (path radiance) values are essential for sensor development. This data is obtained using MODTRAN, often used in conjunction with NVThermIP, and other sensor software. HITRAN and FASCODE are used for laser applications.

Emphasis will be placed on solving real world problems. Four typical scenarios will be presented: ground-to-ground, ground-to-air, air-to- air and ground-to-space scenarios. The importance of transmission and radiance for each scenario will be discussed.

The students are encouraged to bring their specific scenarios to the course to be setup and run. A computer will be available and we will run these scenarios and discuss the results. The attendees will be able to take home model input files to be used at their facilities. We will discuss their cases along with the expected transmission and atmospheric radiance values.

LEARNING OUTCOMES

This course will enable you to:
- present an overview and explain the "theory" of the models: emphasis on MODTRAN
- apply the models to atmospheric transmission/radiance, smart weapons for defense applications, EO sensors development/ evaluations, ground and satellite image correction, hyperspectral imaging, laser spectroscopy laser communications and LIDAR/ LADAR systems.
- evaluate a "basic" problem: You are on the ground looking up to an aircraft. Your partner is on the aircraft looking down at the ground. Do you and your partner measure the same atmospheric transmission? Do you and your partner measure the same radiance? Why?

- identify MODTRAN assumptions, capabilities and limitations
- define basic model inputs – i.e. “MODTRAN for Dummies”
- utilize advanced model inputs such as radiosonde data, Lambertian surfaces, BRDF etc.
- solve and run your own specific scenarios
- compare other models and databases: FASCODE, EOSAEL, HITRAN, NVThermIP etc.

INTENDED AUDIENCE

This course is for engineers and scientist involved in sensor design, sensor evaluation, and remote sensing for solving problems ranging from target detection and identification through global warming.

INSTRUCTOR

John Schroeder is the chief scientist of the Ontar Corporation. He has been involved with the development and use of atmospheric and sensor computer models and atmospheric databases for over 40 years. He has numerous publication in scientific journals and conference presentations in related areas.

Electro-Optical Imaging System Performance

SC154

Course Level: Intermediate
CEU: 0.65 $600 Members | $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

While this course highlights thermal imaging systems, the concepts are generic and can be applied to all imaging systems (CCDs, intensified CCDs, CMOS, and near IR cameras). System analysis could be performed in the spatial domain. However, it is far easier to work in the frequency domain using MTFs. Subsystem MTFs are combined for overall system analysis. This is often called image chain modeling. Although the math is sometimes complex, the equations are graphed for easy understanding. With the Sept 2002 models (e.g., NVTherm), the minimum resolvable temperature (MRT) and minimum resolvable contrast (MRC) are coupled with the target signature and atmospheric transmittance to provide range performance predictions (target acquisition modeling). Three ranges are predicted: detection, recognition, and identification (often shorten to DRI). DRI ranges depend upon the subsystem MTFs, noise (primarily random and fixed pattern noise), the display, and the eye’s response. The two-dimensional (fictitious) spatial frequency approach, three-dimensional noise model, and target discrimination metrics (Johnson’s N50) are applied to performance predictions. The 2007 models (e.g., NVThermIP) employ contrast rather than MRT (MRC) for target acquisition and use V50 as a discrimination metric. Limitations and applications of NVTherm and NVThermIP are discussed with a brief demonstration of the models. Selection and optimization of a specific sensor depends upon a myriad of radiometric, spectral, and spatial parameters (e.g., target signature, atmospheric conditions, optics f-number, field-of-view, and detector responsivity). MTFs and their effect on imagery are interactively demonstrated. Spatial sampling is present in all cameras. Super-resolution reconstruction and microscan minimize sampling artifacts. Several optimization examples are discussed (case study examples).

LEARNING OUTCOMES

This course will enable you to:
- use the correct MTFs for image chain analysis
- describe the radiometric relationship between delta-T and spectral radiance
- compare the differences among scanning, staring, and microscan staring array performance
- recognize the limitations of back-of-the-envelope approximations such as resolution and sensitivity
- identify the subsystem (e.g., motion, optics, detector, electronics, and display) that limits performance
- appreciate limitations of range performance predictions (target acquisition predictions)
- determine if mid-wave (MWIR) or long-wave (LWIR) infrared is appropriate for your application
- appreciate the value of graphs rather than a table of numbers
- be conversant with the myriad of technological terms
- become a smart buyer, analyst, and/or user of imaging systems

INTENDED AUDIENCE

This course is intended for engineers, managers, and buyers who want to understand the wealth of information available from imaging system end-to-end analysis. It is helpful if the students are familiar with linear system theory (MTF analysis).

INSTRUCTOR

Gerald Holst is an independent consultant for imaging system analysis and testing. He was a technical liaison to NATO, research scientist for DoD, and a member of the Lockheed-Martin senior technical staff. Dr. Holst has chaired the SPIE conference Infrared Imaging Systems: Design, Analysis, Modeling and Testing since 1989. He is author of over 30 journal articles and 6 books (published by SPIE and/or JCD Publishing). Dr. Holst is a member of OSA and is a SPIE Fellow.

COURSE PRICE INCLUDES the text *Electro-Optical Imaging System Performance, Fifth Edition* (SPIE Press and JCD Publishing, 2008) by Gerald C. Holst.

Precision Stabilized Pointing and Tracking Systems

SC160

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course provides a practical description of the design, analysis, integration, and evaluation processes associated with development of precision stabilization, pointing and tracking systems. Major topics include stabilized platform technology, electro-mechanical system configuration and analysis, and typical pointing and tracking system architectures.

LEARNING OUTCOMES

This course will enable you to:
- acquire the terminology of stabilization, pointing, and tracking systems and understand the common system architectures and operation
- define typical electro-mechanical configurations and key subsystems and components used in precision stabilization and laser pointing systems
- describe the primary systems engineering tradeoffs and decisions that are required to configure and design stabilization, pointing and tracking systems
- distinguish the performance capabilities of specific design configurations

INTENDED AUDIENCE

This material is designed for engineers and managers responsible for design, analysis, development, or test of electro-optical stabilization, pointing and tracking systems or components. A minimum BS degree in an engineering discipline and familiarity with basic control systems is recommended.

INSTRUCTOR

James Hilkert is president of Alpha-Theta Technologies, an engineering consulting firm specializing in precision pointing, tracking and stabilization applications for clients such as Raytheon, General Dynamics, Northrop Grumman, DRS, Atlantic Positioning and the U.S. Navy. Prior to founding Alpha-Theta Technologies in 1994, he spent 20 years at Texas Instruments Defense Systems (now Raytheon) where he designed inertial tracking and pointing systems for a variety of military applications and later managed the Control Systems Technology Center. He received the Dr. Engineering degree from Southern Methodist University and MSME and BSME degrees from Mississippi State University, is a member of ASME, AIAA and SPIE, and lectures on control systems at The University of Texas at Dallas.

Predicting Target Acquisition Performance of Electro-Optical Imagers

SC181

Course Level: Advanced
CEU: 0.65 $570 Members | $665 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course describes how to predict and evaluate electro-optical (EO) imager performance. Metrics that quantify imager resolution are described. The detection, recognition, and identification tasks are discussed, and the meaning of acquisition probabilities is explained. The basic theory of operation of thermal imagers, image intensifiers, and video cameras is presented. This course describes how to quantify the resolution and noise characteristics of an EO imager. The theory and analysis of sampled imagers is emphasized. Image quality metrics are described, and the relationship between image quality and target acquisition performance is explained. The course provides a complete overview of how to analyze and evaluate the performance of EO imagers.

LEARNING OUTCOMES

This course will enable you to:

- describe what a target acquisition model does
- describe the operation of thermal sensors, video cameras and other EO imagers
- analyze the impact of sampling on targeting performance
- evaluate the targeting performance of an EO imager

INTENDED AUDIENCE

This course is intended for the design engineer or system analyst who is interested in quantifying the performance of EO imagers. Some background in linear systems analysis is helpful but not mandatory.

INSTRUCTOR

Richard Vollmerhausen started his engineering career in 1965 at Douglas Aircraft; he worked instrumentation on the S-IVB Stage of the Saturn Apollo. After two years in the army, he moved to the Naval Weapon Center at China Lake and designed infrared trackers for air-to-air missiles. In the early 1980's, he joined the army's Night Vision lab and became head of the branch developing targeting and pilotage systems for army aviation. In the late 1990's, he headed the Model Development Branch at NVL and developed the target acquisition models currently used by the army. After retirement in 2003, he consulted for government and industry. In 2011, he started graduate studies University of Delaware, receiving his PhD in EE in 2013. Dr. Vollmerhausen is currently Chief Engineer and a founding partner of St. Johns Optical Systems in Lake Mary, Florida.

COURSE PRICE INCLUDES the text *Analysis and Evaluation of Sampled Imaging Systems* (SPIE Press, 2010) by Richard H. Vollmerhausen, Ronald G. Driggers, and Don Reago.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Next Generation Sensors and Systems

Statistics for Imaging and Sensor Data

SC1072

Course Level: Introductory
CEU: 0.65 $575 Members | $670 Non-Members USD
Monday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

- apply the statistical methods suitable for a given context
- demonstrate the statistical significance of your results based on hypothesis testing
- construct confidence intervals for a variety of imaging applications
- fit predictive equations to your imaging data
- construct confidence and prediction intervals for a response variable as a function of predictors
- explain the basics of statistical signal processing and its relationship to linear regression models
- perform correct analysis of outliers in data
- implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics and Graduate Program Chair at the Rochester Institute of Technology. He teaches graduate and undergraduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in a prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text *Statistics for Imaging, Optics, and Photonics* (Wiley, 2011) by Peter Bajorski.

Fundamentals of Fiber Optic Sensor Design and Technology

New

SC1160

Course Level: Introductory
CEU: 0.65 $545 Members | $640 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course explains basic principles and applications of fiber optic sensor technology. A primary goal of the course is to present the underlying principals associated with the design and application of fiber optic sensor technology.

The course begins with an overview of the fundamental components associated with fiber optic sensors and how they interact to form intensity-based and interferometry-based fiber sensors. It then continues with an overview of physical fiber optic sensors starting with intensity-based sensors and continuing with those based on the Mach-Zehnder, Michelson and Sagnac interferometers. A review of fiber gratings and fiber-etalon-based sensors follows. Examples of applications are given in a wide variety of fields including aerospace and defense, civil structures, oil and gas, and composite manufacturing.

The course continues with an examination of the important emerging areas of chemical and biological fiber sensors – including spectroscopic, refractometric, and more exotic types. Applications ranging from biomedical diagnosis to environmental monitoring will be discussed.

Anyone seeking a rapid and effective introduction to the field of fiber optic sensor technology would benefit greatly from this course. It is intended to strongly complement and serve as an introduction to the *Fiber Optic Sensors and Applications Conference* associated with this Symposium.

LEARNING OUTCOMES

This course will enable you to:

- describe the fundamental components associated with most fiber optic sensors
- explain how components interact and how the performance of a fiber sensor depends on these interactions
- identify common intensity-based fiber sensors, their application areas, their advantages and limitations
- compare the relative advantages of different sensor classes (e.g., intrinsic vs. extrinsic, single-point vs. distributed; active vs. passive) and readout techniques (e.g., wavelength vs. intensity, direct vs. modulated, homodyne vs. heterodyne)
- explain the operation of the Mach-Zehnder, Michelson and Sagnac interferometers and how they are being applied in the field
- determine the strain and temperature response of fiber grating sensors
- describe how fiber grating sensors may be used to supported multi-parameter sensing, including pressure and temperature and multi-axis strain
- understand the operation and applications of evanescent-field, optrode-style, and remote-spectroscopic sensors
- explain the application and operation of fiber-etalon-based sensors
- identify classes of chemical and biological fiber sensors
- be familiar with applications of fiber sensors in medical, chemical, environmental, aerospace, defense, oil and gas, civil structure and manufacturing applications

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to design and apply fiber optic sensors to a wide range of applications. Undergraduate training in engineering or science would be of great benefit.

INSTRUCTOR

Eric Udd has been designing and developing fiber optic sensor technology since 1977, at McDonnell Douglas, Blue Road Research and as President of Columbia Gorge Research since January 2006. He has made fundamental contributions to fiber optic rotation, acoustic, pressure, strain, temperature, and moisture sensors. Mr. Udd has 48 issued patents on fiber optic technology and approximately 170 papers. He is a McDonnell Douglas, SPIE and OSA Fellow and in 2009 was awarded the Richardson Medal by OSA for this work in Fiber Optic Sensors and the field of Fiber Optic Smart Structures.

Robert Lieberman has most recently been the President and Chief Technology Officer of Intelligent Optical Systems, Inc., and serves or has served on the Boards of SPIE, Optech, OptiSense LLC, and Optical Security Sensing LLC. Dr. Lieberman's background includes a Ph.D. in physics from the University of Michigan, and a scientific and technical management career at AT&T Bell Laboratories and Physical Optics Corporation notable for inventions and ground-breaking research projects in microelectronic devices, optical biosensors, physical and chemical sensors, and sensor networks. Dr. Lieberman has written over 50 publications, holds 21 U.S. patents, has chaired numerous conferences on optical sensing, and is a Fellow of SPIE.

COURSE PRICE INCLUDES the text *Fiber Optic Sensor Field Guide* (SPIE Press, 2015), by William B. Spillman and Eric Udd.

Introduction to Optical and Infrared Sensor Systems

SC789

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to optical (near UV-visible) and infrared sensor systems, with an emphasis on systems used in defense and security. Topics include both passive imagers and active laser radars (lidar/ladar). We begin with a discussion of radiometry and radiometric calculations to determine how much optical power is captured by a sensor system. We survey atmospheric propagation and phenomenology (absorption, emission, scattering, and turbulence) and explore how these issues affect sensor systems. Finally, we perform signal calculations that consider the source, the atmosphere, and the optical system and detector, to arrive at a signal-to-noise ratio for typical passive and active sensor systems. These principles of optical radiometry, atmospheric propagation, and optical detection are combined in examples of real sensors studied at the block-diagram level. Sensor system examples include passive infrared imagers, polarization imagers, and hyperspectral imaging spectrometers, and active laser radars (lidars or ladars) for sensing distributed or hard targets. The course organization is approximately one third on the radiometric analysis of sensor systems, one third on atmospheric phenomenology and detector parameters, and one third on example calculations and examination of sensor systems at the block-diagram level.

LEARNING OUTCOMES

This course will enable you to:

- explain and use radiometry for describing and calculating the flow of optical energy in an optical or infrared sensor system
- determine the radiometric throughput of sensor systems
- describe atmospheric phenomenology relevant to propagation of optical and infrared radiation
- explain how the atmosphere affects the performance of sensor systems
- use detector parameters with radiometric calculations to predict the signal received by passive and active sensors
- calculate signal-to-noise ratio for typical sensor systems
- explain real-world sensor systems at the block-diagram level
- explain the difference between and important concepts of passive reflection-based and emission-based imaging
- describe the basic operating principles of passive imagers and active laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who find themselves working on (or curious about) optical (uv-vis) and infrared sensor systems without formal training in this area. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Joseph Shaw has been developing optical remote sensing systems and using them in environmental and military sensing for two decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization's Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

Displays

Head-Mounted Displays: Design and Applications

SC159

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Head-mounted displays (HMD) and the military counterpart helmet-mounted displays, are personal information-viewing devices that can provide information in a way that no other display can because the information is always available for viewing. By making the imagery reactive to head and body movements we replicate the way humans view, navigate and explore the world. This unique capability lends itself to applications such as Virtual Reality for creating artificial environments, medical visualization as an aid in surgical procedures, military vehicles for viewing sensor imagery, aircraft simulation and training, and for fixed and rotary wing avionics display applications.

This course covers design fundamentals for head-mounted displays from the user's point of view starting with the basics of human perception, head and neck biomechanics, image sources, optical design and head mounting. We will also discuss the impact of user task requirements and applications on various HMD parameters, as well as a detailed discussion of HMD optical designs (pupil and non-pupil forming, see-through and non-see-through, monocular, biocular and binocular, exit pupil and eye relief).

From there we will delve into various image source technologies, discussing advantages and disadvantages of the various approaches and methods for producing color imagery, with their implications for use in the near-eye presentation of imagery. We will also discuss head/neck anatomy and biomechanics and the implications of HMD weight and center of gravity on crash and ejection safety. Also presented will be guidelines for preventing eye fatigue, neck strain, cybersickness and other adverse physiological effects that have been attributed to poor HMD design. Throughout the course, we will use examples of current HMD systems and hardware to illustrate these issues.

LEARNING OUTCOMES

This course will enable you to:

- define basic components and attributes of head-mounted displays and visually coupled systems
- describe important features and enabling technologies of an HMD and their impact on user performance and acceptance
- identify key user-oriented performance requirements and link their impact on HMD design parameters
- list basic features of the human visual system and biomechanical attributes of the head and neck and the guidelines to follow to prevent fatigue or strain
- identify key tradeoffs for monocular, binocular and biocular systems
- classify current image source technologies and their methods for producing color imagery
- describe methods of producing wide field of view, high resolution HMDs
- evaluate tradeoffs for critical display performance parameters

INTENDED AUDIENCE

This course is intended for managers, engineers and scientists involved in the procurement, evaluation, specification or design of HMDs for air or ground-based applications.

INSTRUCTOR

James Melzer is Manager of Research and Technology at Rockwell Collins Optronics, in Carlsbad, California, where he has been designing head-mounted displays for over 28 years. He holds a BS from Loyola Marymount University and an SM from the Massachusetts Institute of Technology. He has extensive experience in optical and displays engineering, visual human factors, and is an expert in display design for head-mounted systems, aviation life-support, and user interface. His research interests are in visual and auditory perception, cognitive workload reduction, and bio-inspired applications of invertebrate vision. He has authored over 40 technical papers and book chapters and holds four patents in head-mounted display design.

Michael Browne is the Vice President of Product Development at SA Photonics in San Francisco, California. He has a Ph.D. in Optical Engineering from the University of Arizona's Optical Sciences Center. Mike has been involved in the design, test, and measurement of head mounted display systems since 1991. At Kaiser Electronics, Mike led the design of numerous head mounted display and rear-projection display systems, including those for the F-35 Joint Strike Fighter. Mike leads SA Photonics' efforts in the design and development of person-mounted information systems, including body-worn electronics, head-mounted displays and night vision systems. Mike's current research includes investigations into binocular rivalry in head mounted displays, simulator sickness prediction and prevention, and the design of wide field of view night vision systems.

COURSE PRICE INCLUDES the text *Head Mounted Displays: Designing for the User* (republished 2011) by James Melzer and Kirk Moffitt.

Introduction to Night Vision

SC1068

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 1:30 pm to 5:30 pm

Night vision devices have become ubiquitous in both commercial and military environments. From the very high end systems used for aviation, to the low-performance systems sold for outdoorsmen, these devices have changed the way their users operate at night. This course explains the basic principles behind night vision and discusses the different types of night vision devices, both "analog" and "digital". In addition to a survey of night vision devices, we also examine the inner workings of night vision systems and explain them in an easy to understand manner. We will discuss the design of night vision systems, both handheld and head mounted.

Although we will talk briefly about SWIR and thermal devices to differentiate them from night vision devices, this course is primarily aimed at visible and near infra-red (NIR) imagers. Imagery from both night vision cameras as well as thermal imagers will be presented and the differences between them will be compared/contrasted.

LEARNING OUTCOMES

This course will enable you to:
- identify the three basic components of a night vision imager: the sensor, the amplifier and the output component
- specify input optics (objective lenses) and output optics (eyepieces) for both analog and digital night vision devices
- explain the difference between VIS/NIR night vision, SWIR, MWIR and LWIR sensors as well as when each should be chosen
- differentiate the different generations of night vision goggles
- define appropriate light levels for night vision device testing
- describe new digital night vision devices and their advantages and disadvantages
- explain the important attributes of night vision systems and how they should be specified for "best value" performance
- predict night vision performance using NVESD models

INTENDED AUDIENCE

Scientists, engineers, technicians, procurement personnel or managers who wish to learn more about night vision devices. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Michael Browne is the Vice President of Product Development at SA Photonics. He has a Ph.D. in Optical Engineering from the University of Arizona's Optical Sciences Center. Mike has been involved in the design, test and measurement of night vision systems since 1986. At Kaiser Electronics, he led the design of numerous head mounted night vision systems including those for the RAH-66 Comanche helicopter and the USAF NVS program. He leads SA Photonics' efforts in the design and development of person-mounted information systems, including body-worn electronics, head-mounted displays and night vision systems. His current research includes investigations into the design of wide field of view night vision devices, binocular rivalry in head mounted displays, and smear reduction in digital displays.

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:
- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Fundamentals of Electronic Image Processing

SC066

Course Level: Introductory
CEU: 0.65 $585 Members | $680 Non-Members USD
Monday 8:30 am to 5:30 pm

Many disciplines of science and manufacturing acquire and evaluate images on a routine basis. Typically these images must be processed so that important features can be measured or identified This short course introduces the fundamentals of electronic image processing to scientists and engineers who need to know how to manipulate images that have been acquired and stored within a digital computer.

LEARNING OUTCOMES

This course will enable you to:

- describe image storage, acquisition, and digitization
- become familiar with image transforms such as Fourier, Hough, Walsh, Hadamar, Discrete Cosine, and Hotelling
- explain the difference between the types of linear and non-linear filters and when to use each
- learn the difference between types of noise in the degradation of an image
- apply color image processing techniques to enhance key features in color and gray scale images
- recognize image segmentation techniques and how they are used to extract objects from an image
- explain software approaches to image processing
- demonstrate how to use the UCFImage image processing software program included with the course.

INTENDED AUDIENCE

This course will be useful to engineers and scientists who have a need to understand and use image processing techniques, but have no formal training in image processing. It will give the individual insight into a number of complex algorithms as it applies to several different applications of this very interesting and important field.

INSTRUCTOR

Arthur Weeks holds an associate professor position with the Dept. of Electrical and Computer Engineering at the Univ. of Central Florida. He recently left his position as a vice president of corporate technology to continue his research in image processing and bio-medical signal processing. He has published over 30 articles and three books in image processing.

COURSE PRICE INCLUDES the text *Fundamentals of Electronic Image Processing* (SPIE Press, 1996) by Arthur Weeks.

Sensor Data and Information Exploitation

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:

- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Target Detection Algorithms for Hyperspectral Imagery

SC995

Course Level: Introductory
CEU: 0.65 $515 Members | $610 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of automatic target and object detection and its applications in Hyperspectral Imagery (HSI). The primary goal of this course is to introduce the well known target detection algorithms in hyperspectral imagery. Examples of the classical target detection techniques such as spectral matched filter, subspace matched filter, adaptive matched filter, orthogonal subspace, support vector machine (SVM) and machine learning are reviewed. Construction of invariance subspaces for target and background as well as the use of regularization techniques are presented. Standard atmospheric correction and compensation techniques are reviewed. Anomaly detection techniques for HSI and dual band FLIR imagery are also discussed. Applications of HSI for detection of mines, targets, humans, chemical plumes and anomalies are reviewed.

LEARNING OUTCOMES

This course will enable you to:

- describe the fundamental concepts of target detection algorithms as applied to HSI
- learn the procedure to use the generalized maximum likelihood ratio test to design spectral detectors
- describe the fundamental differences between different detection algorithms based on their model representations
- develop statistical models as well as subspace models for HSI data
- explain the difference between anomaly detection and classification
- distinguish between linear and nonlinear approaches (SVM and Kernel learning techniques)
- develop anomaly detection techniques for different environmental scenarios
- describe linear models and unmixing techniques for abundance measures
- plot ROC curves to evaluate the performance of the algorithms

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about target detection in hyperspectral, multispectral or dual-band FLIR imagery. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a senior research scientist (ST) at US Army Research Laboratory (ARL). He is also an adjunct professor in the Electrical and Computer Engineering Department at the Johns Hopkins University. He is actively engaged in research in image processing, neural networks, automatic target recognition, and video compression and its transmission over high speed networks. He has published over 200 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing,IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions for Neural Networks. He is a Fellow of IEEE and SPIE.

Statistics for Imaging and Sensor Data

SC1072

Course Level: Introductory
CEU: 0.65 $575 Members | $670 Non-Members USD
Monday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

- apply the statistical methods suitable for a given context
- demonstrate the statistical significance of your results based on hypothesis testing
- construct confidence intervals for a variety of imaging applications
- fit predictive equations to your imaging data
- construct confidence and prediction intervals for a response variable as a function of predictors
- explain the basics of statistical signal processing and its relationship to linear regression models
- perform correct analysis of outliers in data
- implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics and Graduate Program Chair at the Rochester Institute of Technology. He teaches graduate and undergraduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in a prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text *Statistics for Imaging, Optics, and Photonics* (Wiley, 2011) by Peter Bajorski.

Analog-to-Digital Converters for Digital ROICs

SC1076

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course surveys structure and operation of analog-to-digital converters (ADCs) implemented on digital readout integrated circuits (ROICs) and digital image sensors. Attendees will learn how to evaluate ADC architectures using basic figures of merit for use in different sensor formats. We will cover a wide range of cutting edge architectures and see published examples without delving into transistor level theory. We will survey both academia and industrial ADC architectures. From this survey attendees will discover the industrial design evolution convergence down to a few workhorse architectures and what lessons it imparts to the image sensor community. If you are interested in the digital ROIC revolution or if you ever interface with designers or evaluate digital ROIC proposals, then you will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
- identify analog-to-digital architectures used for creating digital ROICs and image sensors
- calculate ADC architecture figures of merit important to image sensors
- evaluate ADC architecture compatibility with image sensor format and requirements
- infer the direction in which state-of-the-art digital image sensors are headed
- name the top ADC architectures used by commercial industry and explain how this knowledge benefits the image sensor industry
- stimulate your own creativity and help you develop new ideas and applications for digital ROICs and digital image sensors

INTENDED AUDIENCE

This course is intended for engineers and physicists with a background in basic electrical theory (electrical stimuli, resistors, capacitors and block diagramming) who wish to learn about analog-to-digital converter architectures and how they are applied to digital ROICs and digital image sensors. An undergraduate degree in science or engineering is assumed, and basic knowledge of electrical engineering will be particularly helpful.

INSTRUCTOR

Kenton Veeder is a ROIC design engineer, systems engineer, and part time detector physicist. He has been in the defense and commercial image sensor field for over 12 years and is the president of Senseeker Engineering Inc. in Santa Barbara, California. He has nine patents and several publications, one of which earned the MSS Detectors best paper award in 2006. While working for Raytheon he was awarded recognition as Raytheon's 'Father of the Digital Focal Plane Array' and he and his team were given the company wide 'Excellence In Technology' award. Kenton earned his M.S. in electrical engineering from the Analog-and-Mixed Signal Center at Texas A&M University. Kenton is a member of SPIE and IEEE.

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:
- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Precision Stabilized Pointing and Tracking Systems

SC160

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course provides a practical description of the design, analysis, integration, and evaluation processes associated with development of precision stabilization, pointing and tracking systems. Major topics include stabilized platform technology, electro-mechanical system configuration and analysis, and typical pointing and tracking system architectures.

LEARNING OUTCOMES

This course will enable you to:

- acquire the terminology of stabilization, pointing, and tracking systems and understand the common system architectures and operation
- define typical electro-mechanical configurations and key subsystems and components used in precision stabilization and laser pointing systems
- describe the primary systems engineering tradeoffs and decisions that are required to configure and design stabilization, pointing and tracking systems
- distinguish the performance capabilities of specific design configurations

INTENDED AUDIENCE

This material is designed for engineers and managers responsible for design, analysis, development, or test of electro-optical stabilization, pointing and tracking systems or components. A minimum BS degree in an engineering discipline and familiarity with basic control systems is recommended.

INSTRUCTOR

James Hilkert is president of Alpha-Theta Technologies, an engineering consulting firm specializing in precision pointing, tracking and stabilization applications for clients such as Raytheon, General Dynamics, Northrop Grumman, DRS, Atlantic Positioning and the U.S. Navy. Prior to founding Alpha-Theta Technologies in 1994, he spent 20 years at Texas Instruments Defense Systems (now Raytheon) where he designed inertial tracking and pointing systems for a variety of military applications and later managed the Control Systems Technology Center. He received the Dr. Engineering degree from Southern Methodist University and MSME and BSME degrees from Mississippi State University, is a member of ASME, AIAA and SPIE, and lectures on control systems at The University of Texas at Dallas.

Multispectral and Hyperspectral Image Sensors

SC194

Course Level: Advanced
CEU: 0.35 $375 Members | $425 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:

- understand many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
- describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
- list and define the relevant radiometric radiometric quantities, concepts and phenomenology
- understand the process of translating system requirements into sensor hardware constraints and specifications
- analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
- define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
- describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
- list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
- formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
- provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 34 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 63 publications in these technical areas. He is a Fellow of the SPIE.

COURSE PRICE INCLUDES the text *CMOS/CCD Sensors and Camera Systems, 2nd edition* (SPIE Press, 2011) by Terrence Lomheim and Gerald Holst.

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as “black boxes” and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:
- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work
- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world’s leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Imagery and Pattern Analysis

Dimensionality Reduction for Hyperspectral Image Analysis

New

SC1161

Course Level: Intermediate
CEU: 0.35 $295 Members | $345 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Hyperspectral imaging is an emerging technique in remote sensing. The very high spectral resolution in the hundreds of acquired images provides the potential of more accurate detection, classification, and quantification than that obtained using traditional broad-band multispectral imaging sensors. However, the resulting high data dimensionality poses challenges in data analysis. This course explains basic principles of dimensionality reduction that can maintain or even improve the performance of hyperspectral data analysis tasks (e.g., detection, classification).

The primary goal of this course is to introduce the preferred feature extraction and feature selection algorithms for hyperspectral imagery. Specifically, two types of dimensionality reduction techniques, transformation-based and band-selection-based, will be studied. For each category, both supervised (with known class types and samples) and unsupervised (without any prior knowledge) approaches will be presented. In addition to the widely-used approaches, the state-of-the-art algorithms (e.g., manifold learning, sparse regression) will be discussed. Performance of all the techniques is evaluated using several real data experiments.

LEARNING OUTCOMES

This course will enable you to:
- use popular transform-based techniques to reduce the dimensionality of hyperspectral images
- use popular band-selection-based techniques to reduce the dimensionality of hyperspectral images
- quantify the performance of a dimensionality reduction technique
- explain the role of involved parameters in performance variation
- identify the best dimensionality reduction technique for a given hyperspectral data
- recognize the state-of-the-art techniques in hyperspectral image dimensionality reduction

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to effectively analyze hyperspectral remote sensing data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Qian (Jenny) Du has been conducting research on hyperspectral image processing and analysis for more than fifteen years. She has numerous peer-reviewed publications in this field, and developed several well-received algorithms. She currently is Bobby Shackouls Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Dr. Du was a selected lecturer for IEEE Geoscience and Remote Sensing Symposium in 2009-2013, and a selected lecturer for the 5th IEEE GRSS Workshop on Hyperspectral Signal and Image Processing: Evolution in Remote Sensing (WHISPERS). She is an Associate Editor for IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Signal Processing Letters, and SPIE Journal of Applied Remote Sensing.

Precision Stabilized Pointing and Tracking Systems

SC160

Course Level: Intermediate
CEU: 0.65 $515 Members | $610 Non-Members USD
Monday 8:30 am to 5:30 pm

This course provides a practical description of the design, analysis, integration, and evaluation processes associated with development of precision stabilization, pointing and tracking systems. Major topics include stabilized platform technology, electro-mechanical system configuration and analysis, and typical pointing and tracking system architectures.

LEARNING OUTCOMES

This course will enable you to:
- acquire the terminology of stabilization, pointing, and tracking systems and understand the common system architectures and operation
- define typical electro-mechanical configurations and key subsystems and components used in precision stabilization and laser pointing systems

- describe the primary systems engineering tradeoffs and decisions that are required to configure and design stabilization, pointing and tracking systems
- distinguish the performance capabilities of specific design configurations

INTENDED AUDIENCE

This material is designed for engineers and managers responsible for design, analysis, development, or test of electro-optical stabilization, pointing and tracking systems or components. A minimum BS degree in an engineering discipline and familiarity with basic control systems is recommended.

INSTRUCTOR

James Hilkert is president of Alpha-Theta Technologies, an engineering consulting firm specializing in precision pointing, tracking and stabilization applications for clients such as Raytheon, General Dynamics, Northrop Grumman, DRS, Atlantic Positioning and the U.S. Navy. Prior to founding Alpha-Theta Technologies in 1994, he spent 20 years at Texas Instruments Defense Systems (now Raytheon) where he designed inertial tracking and pointing systems for a variety of military applications and later managed the Control Systems Technology Center. He received the Dr. Engineering degree from Southern Methodist University and MSME and BSME degrees from Mississippi State University, is a member of ASME, AIAA and SPIE, and lectures on control systems at The University of Texas at Dallas.

Information Systems and Networks: Processing, Fusion, and Knowledge Generation

Multispectral Image Fusion and Night Vision Colorization

SC1135

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics.

Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These images resemble natural color scenes and thus can improve the observer's performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision.

In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. A FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:
- review the applications and techniques of image fusion and night vision enhancement
- categorize multiscale image fusion methods : image pyramid vs. wavelet transform
- apply quantitative vs. qualitative evaluation
- investigate advanced fusion applications: color fusion and face recognition
- obtain an overview of colorization methods: color mapping, segment-based, channel-based
- evaluate colorized images: qualitative vs. quantitative, and links to the NIIRS (National Imagery Interpretability Rating Scale) ratings
- explore information fusion application to a multispectral stereo face recognition system at four levels: image, feature, score, and decision; qualitatively evaluate performance improvement
- recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision as well as face recognition. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an associate professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of three federal research grants in night vision enhancement, and in multispectral face recognition. He holds two patents in glaucoma classification and face recognition, and has published more than 70 peer-reviewed papers. His research interests include pattern recognition, biometrics, information fusion, and computer-aided diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion evaluation. He received the 2009 IEEE Russ Bioengineering Award and compiled over 30 top ten finishes as part of robotic teams in international contests. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.

Courses for Industry & Exhibitors

Basic Optics for Non-Optics Personnel

SC609

Course Level: Introductory
CEU: 0.2 $100 Members | $150 Non-Members USD
Wednesday 8:30 am to 11:00 am

This course will provide the technical manager, sales engineering, marketing staff, or other non-optics personnel with a basic, non-mathematical introduction to the terms, specifications, and concepts used in optical technology to facilitate effective communication with optics professionals on a functional level. Topics to be covered include basic concepts such as imaging, interference, diffraction, polarization and aberrations, definitions relating to color and optical quality, and an overview of the basic measures of optical performance such as MTF and wavefront error. The material will be presented with a minimal amount of math, rather emphasizing working concepts, definitions, rules of thumb, and visual interpretation of specifications. Specific applications will include defining basic imaging needs such as magnification, depth-of-field, and MTF as well as the definitions of radiometric terms.

LEARNING OUTCOMES

This course will enable you to:
- read optical system descriptions and papers
- ask the right questions about optical component performance
- describe basic optical specifications for lenses, filters, and other components
- assess differences in types of filters, mirrors and beam directing optics
- know how optics is used in our everyday lives

INTENDED AUDIENCE

This course is intended for the non-optical professional who needs to understand basic optics and interface with optics professionals.

INSTRUCTOR

Kevin Harding has been active in the optics industry for over 30 years, and has taught machine vision and optical methods for over 25 years in over 70 workshops and tutorials, including engineering workshops on machine vision, metrology, NDT, and interferometry used by vendors and system houses to train their own engineers. He has been recognized for his leadership in optics and machine vision by the Society of Manufacturing Engineers, Automated Imaging Association, and Engineering Society of Detroit. Kevin is a Fellow of SPIE and was the 2008 President of the Society.

Basic Laser Technology

SC972

Course Level: Introductory
CEU: 0.35 $295 Members | $345 Non-Members USD
Friday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as "black boxes" and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.

LEARNING OUTCOMES

This course will enable you to:
- describe the overall inner workings of any laser
- describe the functionality of the key laser components
- know the difference between how acousto- and electro-optic Q-switches work
- explain how each key component in a laser may contribute to laser performance
- intelligently engage your clients or customers using proper laser terminology
- build stronger relationships with clients and customers by demonstrating product knowledge
- obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE

Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

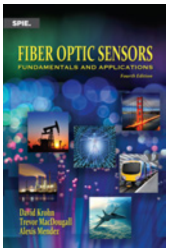
INSTRUCTOR

Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for the some the world's leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

NEW BOOKS FROM SPIE

2015

Price key: SPIE Member $ / Nonmember $

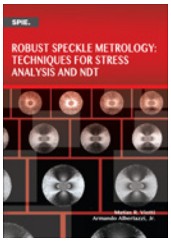


Fiber Optic Sensors: Fundamentals and Applications

David A. Krohn, Trevor MacDougall, and Alexis Mendez

Vol. PM247

Print $73/$86
eBook $62/$73

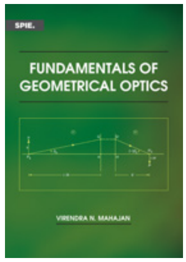


Robust Speckle Metrology Techniques for Stress Analysis and NDT

Matias R. Viotti and Armando Albertazzi, Jr.

Vol. PM251

Print $50/$59
eBook $43/$50

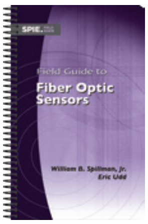


Fundamentals of Geometrical Optics

Virendra N. Mahajan

Vol. PM245

Print $75/$88
eBook $64/$75

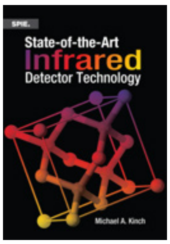


Field Guide to Fiber Optic Sensors

William B. Spillman, Jr. and Eric Udd

Vol. FG34

Print $36/$42
eBook $31/$36



State-of-the-Art Infrared Detector Technology

Michael A. Kinch

Vol. PM248

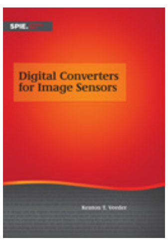
Print $62/$73
eBook $53/$62

Field Guide to Digital Micro-Optics

Bernard C. Kress

Vol. FG33

Print $36/$42
eBook $31/$36

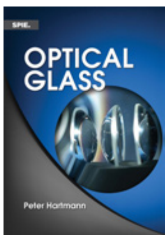


Digital Converters for Image Sensors

Kenton T. Veeder

Vol. TT97

Print $47/$55
eBook $40/$47

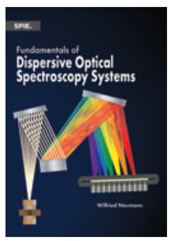


Optical Glass

Peter Hartmann

Vol. PM249

Print $53/$62
eBook $45/$53

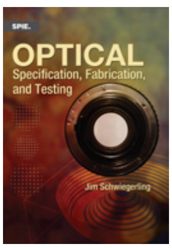


Fundamentals of Dispersive Optical Spectroscopy Systems

Wilfried Neumann

Vol. PM242

Print $56/$66
eBook $48/$56

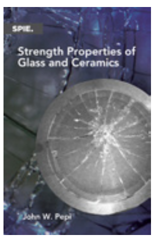


Optical Specification, Fabrication, and Testing

Jim Schwiegerling

Vol. PM252

Print $47/$55
eBook $40/$47



Strength Properties of Glass and Ceramics

John W. Pepi

Vol. PM244

Print $41/$48
eBook $35/$41

SPIE. DSS DEFENSE + SECURITY PROCEEDINGS

SPIE. DSS SENSING TECHNOLOGY + APPLICATIONS PROCEEDINGS

Proceedings.

Full paid registration includes your choice of Proceedings of SPIE (excluding student registrations). See the attached list for product order numbers for proceedings options from this meeting. You will need a product order number when you make your proceedings choice on the registration form.

Available as part of registration:

Symposium CD Collection—a searchable CD of one or multiple proceedings volumes. Available within 8 weeks of the meeting.

Symposium Online Collection—online access to multiple related proceedings volumes via the SPIE Digital Library. Available as papers are published.

Printed Proceedings Volume—a printed book of a single proceedings volume. Available 6 weeks after the meeting.

Online Proceedings Volume—online access to a single proceedings volume via the SPIE Digital Library. Available as papers are published.

You may also purchase additional proceedings products beyond what you choose with your registration plan. **(Note: Single online proceedings volumes not available for separate purchase).** See below for pricing and product order numbers.

Accessing Online Proceedings

Access to purchased online proceedings will be ongoing using your SPIE login credentials; papers are available as they are published.

To access your purchased proceedings:

- Sign in with your SPIE account credentials at **https://spiedigitallibrary.org**. If you do not have an SPIE account, create one using the email address you used to register for the conference.
- Once you have signed in, click the My Account link at the top of the page. You can access your proceedings in the My Conference Proceedings tab.

Note: If your organization subscribes to the SPIE Digital Library, you can also access this content via your organization's account when logging on through your institution's network.

Should you need any assistance, please contact SPIE:
Email: SPIEDLsupport@spie.org
Phone (North America): +1 888 902 0894
Phone (Rest of World): +1 360 685 5580

Proceedings Collections

SPIE DSS DEFENSE+SECURITY

Product Order Number		Collection Title/Included Volumes (See next page for volume titles and editors)	Price for separate purchase
Symposium CD Collection	Symposium Online Collection		Meeting Attendees Only
CDS567	**DLC567**	**Defense, Security, and Sensing 2015: IR Sensors and Systems; Laser Sensors and Systems; and Next Generaton Sensors and Systems** *9451, 9452, 9453, 9461, 9465, 9466, 9467, 9468, and 9469*	**$155**
CDS568	**DLC568**	**Defense, Security, and Sensing 2015: Defense, Homeland Security, and Law Enforcement; and Imaging and Sensing** *9454, 9455, 9456, 9457, 9458, 9459, 9460, 9461, 9462, 9463, and 9464*	**$155**
CDS569	**DLC569**	**Defense, Security, and Sensing 2015: Displays; Sensor Data and Information Exploitation; Imagery and Pattern Analysis; and Information Systems and Networks: Processing, Fusion, and Knowledge Generation** *9470, 9471, 9472, 9473, 9474, 9475, 9476, 9477, 9478, and 9479*	**$155**

SPIE DSS SENSING TECHNOLOGY+APPLICATIONS

Product Order Number		Collection Title/Included Volumes (See next page for volume titles and editors)	Price for separate purchase
Symposium CD Collection	Symposium Online Collection		Meeting Attendees Only
CDS570	**DLC570**	**Sensing Technology and Applications 2015: Imaging and Sensing Technologies; and Sensing for Industry, Environment, and Health** *9480, 9481, 9482, 9483, 9484, 9485, 9486, 9487, 9488, 9489, 9490, and 9491*	**$155**
CDS571	**DLC571**	**Sensing Technology and Applications 2015: Emerging Technologies; Data Visualization; and Information Systems and Networks: Processing, Fusion, and Knowledge Generation** *9492, 9493, 9494, 9495, 9496, 9497, 9498, 9499, 9500, and 9501*	**$155**

Single Proceedings Volumes from Defense + Security

Online proceedings volumes are not available for separate purchase.

Product Order Number: Printed Proceedings Volume	Product Order Number: Online Proceedings Volume	Volume Title/Volume Editors	Price for print volume separate purchase (Meeting Attendees Only)
9451	DL9451	**Infrared Technology and Applications XLI** *Bjørn F. Andresen, Gabor F. Fulop, Charles M. Hanson, Paul R. Norton*	$125
9452	DL9452	**Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXVI** *Gerald C. Holst, Keith A. Krapels*	$70
9453	DL9453	**Window and Dome Technologies and Materials XIV** *Brian J. Zelinski*	$53
9454	DL9454	**Detection and Sensing of Mines, Explosive Objects, and Obscured Targets XX** *Steven S. Bishop, Jason C. Isaacs*	$90
9455	DL9455	**Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XVI** *Augustus Way Fountain*	$70
9456	DL9456	**Sensors, and Command, Control, Communications, and Intelligence (C3I) Technologies for Homeland Security, Defense, and Law Enforcement XIV** *Edward M. Carapezza*	$80
9457	DL9457	**Biometric and Surveillance Technology for Human and Activity Identification XII** *Ioannis A. Kakadiaris, Ajay Kumar, Walter J. Scheirer*	$53
9458	DL9458	**Cyber Sensing 2015** *Igor V. Ternovskiy, Peter Chin*	$45
9459	DL9459	**Ocean Sensing and Monitoring VII** *Weilin W. Hou, Robert A. Arnone*	$60
9460	DL9460	**Airborne Intelligence, Surveillance, Reconnaissance (ISR) Systems and Applications XII** *Daniel J. Henry, Gregory J. Gosian, Davis A. Lange, Dale Linne von Berg, Thomas J. Walls, Darrell L. Young*	$53
9461	DL9461	**Radar Sensor Technology XIX; and Active and Passive Signatures VI** *Kenneth I. Ranney, Armin Doerry, G. Charmaine Gilbreath, Chadwick Todd Hawley*	$90
9462	DL9462	**Passive and Active Millimeter-Wave Imaging XVIII** *David A. Wikner, Arttu R. Luukanen*	$53
9463	DL9463	**Motion Imagery: Standards, Quality, and Interoperability** *Donnie Self*	$53
9464	DL9464	**Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR VI** *Tien Pham, Michael A. Kolodny*	$60
9465	DL9465	**Laser Radar Technology and Applications XX; and Atmospheric Propagation XII** *Monte D. Turner, Gary W. Kamerman, Linda M. Wasiczko Thomas, Earl J. Spillar*	$60

Product Order Number: Printed Proceedings Volume	Product Order Number: Online Proceedings Volume	Volume Title/Volume Editors	Price for print volume separate purchase (Meeting Attendees Only)
9466	DL9466	**Laser Technology for Defense and Security XI** *Mark Dubinskii, Stephen G. Post*	$60
9467	DL9467	**Micro- and Nanotechnology Sensors, Systems, and Applications VII** *Thomas George, Achyut K. Dutta, M. Saif Islam*	$135
9468	DL9468	**Unmanned Systems Technology XVII** *Robert E. Karlsen, Douglas W. Gage, Charles M. Shoemaker, Grant R. Gerhart*	$53
9469	DL9469	**Sensors and Systems for Space Applications VIII** *Khanh D. Pham, Genshe Chen*	$53
9470	DL9470	**Display Technologies and Applications for Defense, Security, and Avionics IX; and Head- and Helmet-Mounted Displays XX** *Daniel D. Desjardins, Kalluri R. Sarma, Peter L. Marasco, Paul R. Havig*	$60
9471	DL9471	**Degraded Visual Environments: Enhanced, Synthetic, and External Vision Solutions 2015** *Jeff J. Güell, Jack Sanders-Reed*	$53
9472	DL9472	**Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XXI** *Miguel Velez-Reyes, Fred A. Kruse*	$90
9473	DL9473	**Geospatial Informatics, Fusion, and Motion Video Analytics V** *Matthew F. Pellechia, Kannappan Palaniappan, Peter J. Doucette, Shiloh L. Dockstader, Gunasekaran Seetharaman*	$53
9474	DL9474	**Signal Processing, Sensor/Information Fusion, and Target Recognition XXIV** *Ivan Kadar*	$80
9475	DL9475	**Algorithms for Synthetic Aperture Radar Imagery XXII** *Edmund Zelnio, Frederick D. Garber*	$53
9476	DL9476	**Automatic Target Recognition XXV** *Firooz A. Sadjadi, Abhijit Mahalanobis*	$60
9477	DL9477	**Optical Pattern Recognition XXVI** *David Casasent, Mohammad S. Alam* (Volume will be available onsite)	$60
9478	DL9478	**Modeling and Simulation for Defense Systems and Applications X** *Eric J. Kelmelis*	$45
9479	DL9479	**Open Architecture/Open Business Model Net-Centric Systems and Defense Transformation 2015** *Raja Suresh*	$53

Single Proceedings Volumes from Sensing Technology

Online proceedings volumes are not available for separate purchase.

Product Order Number		Volume Title/Volume Editors	Price for print volume separate purchase
Printed Proceedings Volume	Online Proceedings Volume		Meeting Attendees Only
9480	DL9480	**Fiber Optic Sensors and Applications XII** *Gary Pickrell, Eric Udd, Henry H. Du*	$60
9481	DL9481	**Image Sensing Technologies: Materials, Devices, Systems, and Applications II** *Nibir K. Dhar, Achyut K. Dutta*	$70
9482	DL9482	**Next-Generation Spectroscopic Technologies VIII** *Mark A. Druy, Richard A. Crocombe, David P. Bannon*	$80
9483	DL9483	**Terahertz Physics, Devices, and Systems IX: Advanced Applications in Industry and Defense** *Mehdi F. Anwar, Thomas W. Crowe, Tariq Manzur*	$60
9484	DL9484	**Compressive Sensing IV** *Fauzia Ahmad*	$53
9485	DL9485	**Thermosense: Thermal Infrared Applications XXXVII** *Sheng-Jen (Tony) Hsieh*	$90
9486	DL9486	**Advanced Environmental, Chemical, and Biological Sensing Technologies XII** *Tuan Vo-Dinh, Robert A. Lieberman, Günter G. Gauglitz*	$60
9487	DL9487	**Smart Biomedical and Physiological Sensor Technology XII** *Brian M. Cullum, Eric S. McLamore*	$60
9488	DL9488	**Sensing for Agriculture and Food Quality and Safety VII** *Moon S. Kim, Kuanglin Chao, Bryan A. Chin*	$60
9489	DL9489	**Dimensional Optical Metrology and Inspection for Practical Applications IV** *Kevin G. Harding, Toru Yoshizawa*	$53
9490	DL9490	**Advances in Global Health through Sensing Technologies 2015** *Šárka O. Southern*	$53
9491	DL9491	**Sensors for Extreme Harsh Environments II** *Debbie G. Senesky, Sachin Dekate*	$53

Product Order Number		Volume Title/Volume Editors	Price for print volume separate purchase
Printed Proceedings Volume	Online Proceedings Volume		Meeting Attendees Only
9492	DL9492	**Advanced Photon Counting Techniques IX** *Mark A. Itzler*	$60
9493	DL9493	**Energy Harvesting and Storage: Materials, Devices, and Applications VI** *Nibir K. Dhar, Achyut K. Dutta*	$53
9494	DL9494	**Next-Generation Robotics II; and Machine Intelligence and Bio-inspired Computation: Theory and Applications IX** *Dan Popa, Muthu B. J. Wijesundara, Misty Blowers*	$53
9495	DL9495	**Three-Dimensional Imaging, Visualization, and Display 2015** *Bahram Javidi, Jung-Young Son*	$70
9496	DL9496	**Independent Component Analyses, Compressive Sampling, Large Data Analyses (LDA), Neural Networks, Biosystems, and Nanoengineering XIII** *Harold H. Szu*	$53
9497	DL9497	**Mobile Multimedia/Image Processing, Security, and Applications 2015** *Sos S. Agaian, Sabah A. Jassim, Eliza Yingzi Du*	$60
9498	DL9498	**Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2015** *Jerome J. Braun*	$45
9499	DL9499	**Next-Generation Analyst III** *Barbara D. Broome, Timothy P. Hanratty, David L. Hall, James Llinas*	$45
9500	DL9500	**Quantum Information and Computation XIII** *Eric Donkor, Andrew R. Pirich, Michael Hayduk*	$80
9501	DL9501	**Satellite Data Compression, Communications, and Processing XI** *Bormin Huang, Chein-I Chang*	$70

GENERAL INFORMATION

REGISTRATION

Onsite Registration and Badge Pick-Up Hours
Pratt St. Lobby (Level 300)

Sunday 19 April . . . . 4:00 pm to 7:00 pm
Monday 20 April . . . . 7:00 am to 5:00 pm
Tuesday 21 April . . . . 7:30 am to 5:00 pm
Wednesday 22 April. 7:30 am to 5:00 pm
Thursday 23 April . . . . 7:30 am to 5:00 pm
Friday 24 April. . . . . 7:30 am to 12:00 pm

CONFERENCE REGISTRATION

Includes admission to all conference sessions, plenaries, panels, and poster sessions, admission to the Exhibition, Welcome Reception, coffee breaks, and a choice of proceedings. Student pricing does not include proceedings.

COURSE AND WORKSHOP REGISTRATION

Courses and workshops are priced separately. Course-only registration includes your selected course(s), course notes, coffee breaks, and admittance to the exhibition. Course prices include applicable taxes. Onsite, please go to Course Materials Pickup after you pick up your badge.

Multiple facilities may be used for courses; allow yourself enough time to register, pick up your materials and possibly walk to a nearby facility before your course begins.

EXHIBITION REGISTRATION

Exhibition-only visitor registration is complimentary.

EARLY REGISTRATION PRICING AND DATES

Conference registration prices increase by $150 USD after 3 April 2015. Course prices increase $75 after 3 April 2015. The online form will automatically display the increased prices.

SPIE MEMBER, SPIE STUDENT MEMBER, AND STUDENT PRICING

- SPIE Members receive conference and course registration discounts. Discounts are applied at the time of registration.
- SPIE Student Members receive a 50% discount on all courses.
- Student registration rates are available only to undergraduate and graduate students who are enrolled full time and have not yet received their Ph.D. Post-docs may not register as students. A student ID number or proof of student status is required with your registration.

PRESS REGISTRATION

For credentialed press and media representatives only. Please email contact information, title, and organization to media@spie.org.

SPIE Cashier

Registration Area
Open during registration hours

REGISTRATION PAYMENTS

If you are paying by cash or check as part of your onsite registration, wish to add a course, workshop, or special event requiring payment, or have questions regarding your registration, visit the SPIE Cashier.

RECEIPTS AND CERTIFICATE OF ATTENDANCE

Preregistered attendees who did not receive a receipt or attendees who need a Certificate of Attendance may obtain those from the SPIE Cashier at Badge Corrections and Receipts.

BADGE CORRECTIONS

Badge corrections can be made by the SPIE Cashier at the Badge Corrections station. Please have your badge removed from the badge holder and marked with your changes before approaching the counter.

REFUND INFORMATION

There is a $50 USD service charge for processing refunds. Requests for refunds must be received by 9 April 2015; all registration fees will be forfeited after this date. Membership dues, SPIE Digital Library subscriptions or Special Events purchased are not refundable.

U.S. GOVERNMENT CREDIT CARDS

U.S. Government credit card users: have your purchasing officer contact the credit card company and get prior authorization before attempting to register. Advise your purchasing agent that SPIE is considered a 5968 company for authorization purposes.

ONSITE SERVICES

Internet Access

WIRED

Pratt St. Lobby (Level 300) – near SPIE Bookstore

Complimentary wired Internet access is available; attendees can hook up their laptops or use provided workstations.

WIRELESS

Pratt St. Lobby (Level 300)
Camden Lobby (Level 300)
Hall D (Level 100), in the DSS EXPO Hall

Complimentary wireless access is also available; instructions will be posted onsite.

SPIE Conference and Exhibition App

Bookstore and Speaker Check-in Desk (Level 300)
Pratt St. Lower Lobby (Level 100)
Camden Lobby (Level 300)

Search and browse the program, special events, participants, courses, and more. Search exhibitors by name or booth numbers, browse products, and search technologies. Free Conference Apps available for iPhone and Android smart phones.

SPIE Bookstore

Pratt St. Lobby (Level 300)

The SPIE Bookstore is your source for the latest SPIE Press Books, Proceedings, and Education and Professional Development materials. Become an SPIE member, explore the Digital Library, take home a free SPIE poster, or buy a souvenir (tie, t-shirt, educational toys, and more).

SPIE Education Services

Pratt St. Lobby (Level 300)

Browse course offerings and the other education services available: SPIE courses, videos, and CDs, as well as customized in-company courses.

SPIE Press Room

Pratt St. East Show Office (Level 200)
Open during Registration hours

For Registered Press only. The Press Room provides meeting space, refreshments, access to exhibitor press releases, and Internet connections. Press are urged to register before the meeting by emailing name, contact information, and name of publication to media@spie.org. Preregistration closes approximately 10 days before the start of the event.

SPIE Luggage + Coat Check

Pratt St. Lobby (Level 300) – Room 338
Monday through Friday

Complimentary luggage, package, and coat storage are available. Please note hours; no late pickup available.

Baltimore Convention Center Business Center

Pratt St. Lobby (Level 300)
Monday through Friday

The Business Center provides full service business needs for your convenience. They provide photocopying, faxing, computer workstations and printing services. Shipping is provided through FedEx. Office supplies are also available. Phone 410-649-7194 for more details.

Restaurant & City Information

Pratt St. Lobby (Level 300)
Monday through Thursday

The information table, near the escalators, will have printed material for those who would like to know more about restaurants and city information.

Child Care Services:

- Elizabeth Cooney Agency Inc., Toll Free: 888-353-1700, Phone: 410-323-1700, Fax: 410-377-4722
- **NOTE:** SPIE does not imply an endorsement nor recommendation of these services. They are provided on an "information only" basis for your further analysis and decision. Other services may be available.

Urgent Message Line

An urgent message line is available during registration hours: 410.649.6102.

Lost and Found

Pratt St. Lobby – Cashier
Open during Registration hours

Found items will be kept at Cashier. At the end of the meeting, all found items will be turned over to Baltimore Convention Center's Public Safety Office, 410.649.7055.

GENERAL INFORMATION

AUTHOR / PRESENTER INFORMATION

Speaker Check-In and Preview Station
Pratt St. Lobby West (Level 300)

Monday through Friday . . . . 7:30 am to 5:00 pm

All conference rooms have a computer workstation, projector, screen, lapel microphone, and laser pointer. All presenters are requested to come to Speaker Check-In with their memory devices or laptops to confirm their presentation display settings.

Poster Setup Instructions

Mezzanine (Level 200)

Tuesday 21 April
Thursday 23 April

Poster presenters must set up their posters between 7:30 am and 5:00 pm on the day of their poster session.

- Paper numbers will be posted in the poster boards in numerical order; please find your poster number and set up your poster in the designated space.
- Presenters who have not set up their poster by 5:00 pm on the day of their presentation will be considered a "no show" and their manuscript will not be published.
- A poster author or coauthor is required to stand by the poster during the scheduled poster session to answer questions from attendees.
- It is your responsibility to remove your poster at the end of the session.
- Posters and all other material not removed will be considered unwanted and will be discarded.

FOOD AND BEVERAGE SERVICES

Coffee Breaks

Pratt St. Lobby (Level 300) & Camden Lobby (Level 300)
Monday, Thursday afternoon, and Friday

Two locations in the Exhibition Hall (Level 100)
Tuesday through Thursday morning

Complimentary coffee will be served twice daily, at 10:00 am and 3:00 pm. Check individual conference listings for exact times and locations.

Food & Refreshments for Purchase

MARKET FRESH CAFÉ - Main Terrace (Level 300)

STARBUCKS - Pratt St. Lobby (Level 300)

Monday through Friday - hours posted

EXHIBITION HALLS - (Level 100)

Tuesday through Thursday during exhibition hours

Hot and cold snacks, hot entrees, deli sandwiches, salads, and pastries are available for purchase, including espresso and beverages. Cash and credit cards accepted.

DESSERTS

Complimentary tickets for dessert snacks are included in course and conference attendee registration packets.

TRAVEL/TRANSPORTATION

ABOUT BALTIMORE

Known as "Charm City," Baltimore is the largest city in the state of Maryland and has become a top tourist destination. Baltimore's temperature in April ranges from 64.5–73.9 degrees Farenheit. The name Baltimore comes from Lord Baltimore, the founder and proprietor of the colony of Maryland.

Baltimore is an alluring, romantic city with lovely attractions and cozy restaurants. Baltimore features a beautiful waterfront, world-class museums, African-American traditional sites, and festivals and cultural events. The 13th largest city in the U.S., Baltimore offers visitors so much to see and do. Baltimore is famous for its Inner Harbor lined with attractions, restaurants, shopping - all within a quick walk of the Baltimore Convention Center. Take advantage of the fast, free and green Charm City Circulator or water taxis, trolley tours and harbor cruises.

Baltimore is close to Washington, D.C. The area is full of American history and culture and makes for a great family vacation destination.

BALTIMORE, MD AIRPORT

Baltimore Washington International Thurgood Marshall Airport (BWI) is conveniently located south of Baltimore, Maryland, approximately 10 miles from the Baltimore Convention Center and the SPIE contracted hotels. The Light Rail runs directly from BWI to downtown Baltimore and the Baltimore Convention Center. Phone: 800.435.9294 or 410.859.7111

WASHINGTON, DC AIRPORTS

Ronald Reagan Washington National Airport (DCA) is located in Arlington County, Virginia, and is the closest airport to downtown Washington, D.C., and Union Station. Phone: 703.417.8000

Dulles International Airport (IAD) is 26 miles from Washington, D.C., in Chantilly, Virginia. Dulles is about a 40-minute drive from downtown Washington, D.C., (in non-rush hour traffic). Union Station in Washington, D.C., offers train service to Baltimore with a station near BWI. Phone: 703.572.2700

TRAIN SERVICE FROM REAGAN WASHINGTON NATIONAL AIRPORT (DCA) TO BALTIMORE WASHINGTON INTERNATIONAL THURGOOD MARSHALL AIRPORT (BWI)

- From DCA, take SuperShuttle to Washington Union Station (WAS). SuperShuttle offers a discount for roundtrip reservations, normally $14 one way. From WAS (Union Station), take the Amtrak train to Baltimore Washington Airport (BWI) Amtrak Station. Then catch the Light Rail to the Baltimore Convention Center Station and further stops servicing the downtown hotels. BWI is located approximately 45 miles north of Washington, D.C.
- From DCA, an alternate method of transportation to Washington Union Station (WAS) is the Metrorail. At DCA, locate the Metrorail station connected to the concourse level of Terminals B and C. Take the YELLOW line (towards Mt. Vernon) to Gallery Place Chinatown Metro Station. Change lines there to the RED line (toward Silver Spring) to Union Station (WAS). The fare is approximately $4 one way on the Metrorail (subject to change). From Union Station, take the Amtrak train to Baltimore WA Airport (BWI) Amtrak Station. Then catch the Light Rail to the Baltimore Convention Center Station and further stops servicing the downtown hotels.
- AMTRAK - Amtrak FARES range from $15 - $37 depending on the route and trip time you choose from Union Station to BWI. The 2110 Acela Express $37 is a faster trip (21 minutes), with fewer stops, and reserved seats from Union Station to/from BWI. 84 Northeast Regional is $15 (25 minutes). 176 Northeast Regional and 94 Northeast Regional are both $21 (27 minutes). Fares depend on fastest routes and departure times. See Amtrak Schedules for all routes.
- From BWI, take the Light Rail to the Convention Center stop by Baltimore Convention Center or further stops servicing the downtown hotels.
- MARC (Maryland Area Regional Commuter) operates Monday through Friday ONLY. MARC runs on the Penn Line from Baltimore/Camden Station to Washington Union Station ($7 one way subject to change) and takes just over 1 hour each way. The Baltimore Convention Center is on the Camden Line. The Penn Line and the Camden Line never meet. Therefore from BWI, take the Light Rail along the Camden Line to the Baltimore Convention Center stop.
- METRO SUBWAY - The Metro Subway System travels to/from Baltimore suburbs and John Hopkins Hospital. It does NOT travel to/from Baltimore Washington International Airport.

TRANSPORTATION FROM BALTIMORE WASHINGTON INTERNATIONAL AIRPORT (BWI)

- SUPERSHUTTLE has offered a discount rate (code 2N83B) for all attending SPIE DSS 2015. Discount rate applies ONLY when booked in advance. Super Shuttle runs 24/7. Book SuperShuttle Online with Discount Code 2N83B - Discount applies for roundtrip reservations.
- TAXI rates from BWI to the Baltimore Convention Center and downtown Baltimore hotels ranges from $25 - $35 one way based on traffic and time of day. Locate the taxi stand just outside baggage claim area of the lower level of the BWI terminal.
- Light Rail from BWI to downtown Baltimore, Convention Center and Hotels
- Charm City Circulator (free transportation) around downtown Baltimore

DRIVING DIRECTIONS AND PARKING FROM BWI TO BALTIMORE CONVENTION CENTER & SPIE HOTELS CAN BE FOUND ONLINE

Car Rental

Hertz Car Rental has been selected as the official car rental agency for this Symposium. To reserve a car, identify yourself as a DSS 2015 Symposium attendee using the Hertz Meeting Code CV# 029B0018. Discount rates apply for rentals up to one week prior through one week after the conference dates. Note: When booking from International Hertz locations, the CV # must be quoted with the letters CV before the number, i.e. CV029B0018. To book online: **www.hertz.com/rentacar/reservation**, please note that the CV# is already incorporated into the link. Book Hertz Online

- In the United States call 1 800.654.2240.
- In Canada call 1 800.263.0600, or 1 416.620.9620 in Toronto.
- In Europe and Asia call the nearest Hertz Reservation Center or travel agent.
- Outside of these areas call 1 405.749.4434.

BALTIMORE AREA.

This colorful, diverse city is Maryland's largest, known for its beautiful harbor, distinct and historic neighborhoods, unique museums, and as a world-class business, academic and industry hub. Proximity to national monuments and museums makes for a great family vacation.

Acceptance of Policies and Registration Conditions

The following Policies and Conditions apply to all SPIE Events. As a condition of registration, you will be required to acknowledge and accept the SPIE Registration Policies and Conditions contained herein.

Granting Attendee Registration and Admission

SPIE, or their officially designated event management, in their sole discretion, reserves the right to accept or decline an individual's registration for an event. Further, SPIE, or event management, reserves the right to prohibit entry or remove any individual whether registered or not, be they attendees, exhibitors, representatives, or vendors, who in their sole opinion are not, or whose conduct is not, in keeping with the character and purpose of the event. Without limiting the foregoing, SPIE and event management reserve the right to remove or refuse entry to any attendee, exhibitor, representative, or vendor who has registered or gained access under false pretenses, provided false information, or for any other reason whatsoever that they deem is cause under the circumstances.

Misconduct Policy

SPIE is a professional, not-for-profit society committed to providing valuable conference and exhibition experiences. SPIE is dedicated to equal opportunity and treatment for all its members and meeting attendees. Attendees are expected to be respectful to other attendees, SPIE staff, and contractors. Harassment and other misconduct will not be tolerated; violators will be asked to leave the event.

Identification

To verify registered participants and provide a measure of security, SPIE will ask attendees to present a government-issued Photo ID at registration to collect registration materials.

Individuals are not allowed to pick up badges for attendees other than themselves. Further, attendees may not have some other person participate in their place at any conference-related activity. Such other individuals will be required to register on their own behalf to participate.

Capture and Use of a Person's Image

By registering for an SPIE event, I grant full permission to SPIE to capture, store, use, and/or reproduce my image or likeness by any audio and/or visual recording technique (including electronic/digital photographs or videos), and create derivative works of these images and recordings in any SPIE media now known or later developed, for any legitimate SPIE marketing or promotional purpose.

By registering for an SPIE event, I waive any right to inspect or approve the use of the images or recordings or of any written copy. I also waive any right to royalties or other compensation arising from or related to the use of the images, recordings, or materials. By registering, I release, defend, indemnify and hold harmless SPIE from and against any claims, damages or liability arising from or related to the use of the images, recordings or materials, including but not limited to claims of defamation, invasion of privacy, or rights of publicity or copyright infringement, or any misuse, distortion, blurring, alteration, optical illusion or use in composite form that may occur or be produced in taking, processing, reduction or production of the finished product, its publication or distribution.

Payment Method

Registrants for paid elements of the event, who do not provide a method of payment, will not be able to complete their registration. Individuals with incomplete registrations will not be able to attend the conference until payment has been made. SPIE accepts VISA, MasterCard, American Express, Discover, Diner's Club, checks and wire transfers. Onsite registrations can also pay with Cash.

Authors/Coauthors

By submitting an abstract, you agree to the following conditions:

- An author or coauthor (including keynote, invited, and solicited speakers) will register at the author registration rate, attend the meeting, and make the presentation as scheduled.
- A full-length manuscript (minimum 6 pages) for any accepted oral or poster presentation will be submitted for publication in the SPIE Digital Library, printed conference Proceedings, and CD. (Some SPIE events have other requirements that the author is made aware of at the time of submission.)
- Only papers presented at the conference and received according to publication guidelines and timelines will be published in the conference Proceedings and SPIE Digital Library (or via the requirements of that event).

Audio, Video, Digital Recording Policy

Conferences, courses, and poster sessions: For copyright reasons, recordings of any kind are prohibited without prior written consent of the presenter or instructor. Attendees may not capture or use the materials presented in any meeting/course room or in course notes on display without written permission. Consent forms are available at Speaker Check-In. Individuals not complying with this policy will be asked to leave a given session and/or asked to surrender their recording media.

EXHIBITION HALL: For security and courtesy reasons, recordings of any kind are prohibited unless one has explicit permission from on-site company representatives. Individuals not complying with this policy will be asked to surrender their recording media and to leave the exhibition hall.

Your registration signifies your agreement to be photographed or videotaped by SPIE in the course of normal business. Such photos and video may be used in SPIE marketing materials or other SPIE promotional items.

Laser Pointer Safety Information/Policy

SPIE supplies tested and safety-approved laser pointers for all conference meeting rooms. For safety reasons, SPIE requests that presenters use provided laser pointers.

Use of a personal laser pointer represents user's acceptance of liability for use of a non-SPIE-supplied laser pointer. If you choose to use your own laser pointer, it must be tested to ensure <5 mW power output. Laser pointers in Class II and IIIa (<5mW) are eye safe if power output is correct, but output must be verified because manufacturer labeling may not match actual output. Come to Speaker Check-In and test your laser pointer on our power meter. You are required to sign a waiver releasing SPIE of any liability for use of potentially non-safe, personal laser pointers. Misuse of any laser pointer can lead to eye damage.

Access to Technical and Networking Events

Persons under the age of 18 including babies, carried or in strollers, and toddlers are not allowed in technical or networking events. Anyone 18 or older must register as an attendee. All technical and networking events require a valid conference badge for admission.

Underage Persons on Exhibition Floor Policy

For safety and insurance reasons:

- No persons under the age of 18 will be allowed in the exhibition area during move-in and move-out.
- Children 14 and older, accompanied by an adult, will be allowed in the exhibition area during open exhibition hours only.
- All children younger than 14, including babies in strollers and toddlers, are not allowed in the exhibition area at any time.

Unauthorized Solicitation Policy

Unauthorized solicitation in the Exhibition Hall is prohibited. Any non-exhibiting manufacturer or supplier observed to be distributing information or soliciting business in the aisles, or in another company's booth, will be asked to leave immediately.

Unsecured Items Policy

Personal belongings should not be left unattended in meeting rooms or public areas. Unattended items are subject to removal by security. SPIE is not responsible for items left unattended.

Wireless Internet Service Policy

At SPIE events where wireless is included with your registration, SPIE provides wireless access for attendees during the conference and exhibition but cannot guarantee full coverage in all locations, all of the time. Please be respectful of your time and usage so that all attendees are able to access the internet.

Excessive usage (e.g., streaming video, gaming, multiple devices) reduces bandwidth and increases cost for all attendees. No routers may be attached to the network. Properly secure your computer before accessing the public wireless network. Failure to do so may allow unauthorized access to your laptop as well as potentially introduce viruses to your computer and/or presentation. SPIE is not responsible for computer viruses or other computer damage.

Mobile Phones and Related Devices Policy

Mobile phones, tablets, laptops, pagers, and any similar electronic devices should be silenced during conference sessions. Please exit the conference room before answering or beginning a phone conversation.

Smoking

For the health and consideration of all attendees, smoking, including e-cigarettes, is not permitted at any event elements, such as but not limited to: plenaries, conferences, workshops, courses, poster sessions, hosted meal functions, receptions, and in the exhibit hall. Most facilities also prohibit smoking and e-cigarettes in all or specific areas. Attendees should obey any signs preventing or authorizing smoking in specified locations.

Hold Harmless

Attendee agrees to release and hold harmless SPIE from any and all claims, demands, and causes of action arising out of or relating to your participation in the event you are registering to participate in and use of any associated facilities or hotels.

Event Cancellation

If for some unforeseen reason SPIE should have to cancel the event, registration fees processed will be refunded to registrants. Registrants will be responsible for cancellation of travel arrangements or housing reservations and the applicable fees.

Confidential Reporting of Unethical or Inappropriate Behavior

SPIE is an organization with strong values of responsibility and integrity. Our Ethics Statement and Code of Professional Conduct contain general guidelines for conducting business with the highest standards of ethics. SPIE has established a confidential reporting system for staff & other stakeholders to raise concerns about possible unethical or inappropriate behavior within our community. Complaints may be filed by phone or through the website, and, if preferred, may be made anonymously. The web address is www.SPIE.ethicspoint.com and the toll free hotline number is 1-888-818-6898.

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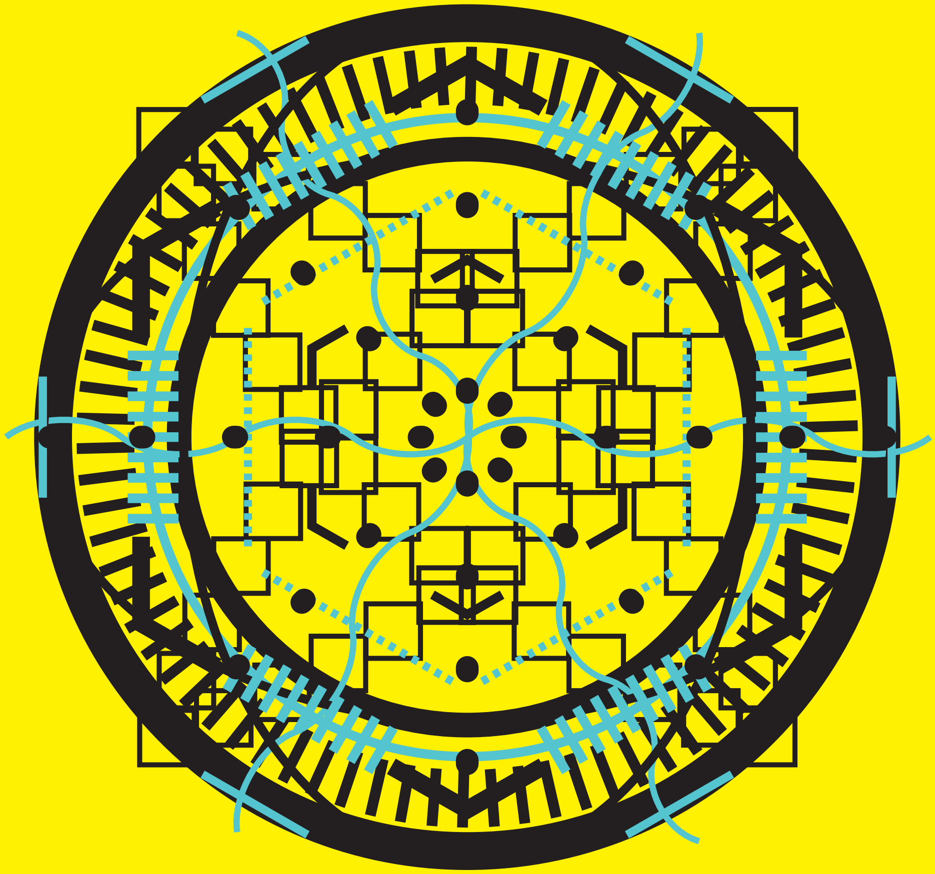
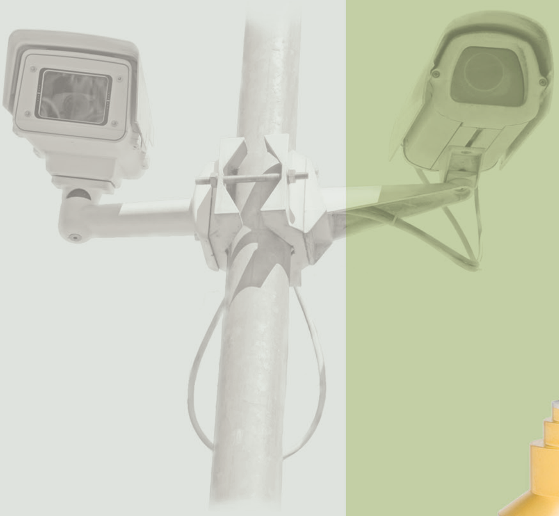


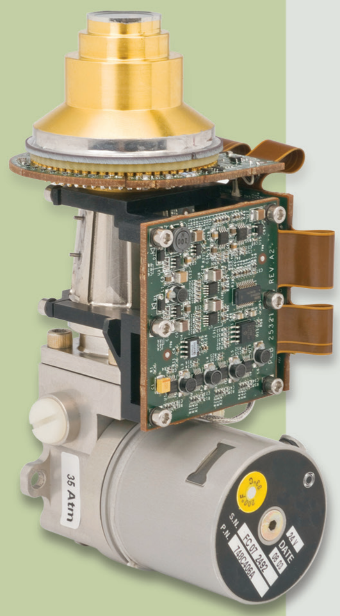
Company	Country	Comment	Reference
Fraunhofer Institute	Germany	T2SL, QWIP, InGaAs	http://www.iaf.fraunhofer.de/en/institute.html
Debut Optoelectroni Sensor Co	China	QWIP	http://www.wopuopto.com/en/product.asp?id=141&classid=13
IQE, UK Operations	UK	MCT	http://www.iqep.com/contact-us/
IntelliEpi-Soitec	France	?	http://www.soitec.com/en/
Brolis Semiconductors	Lithuania	?	http://brolis-semicon.com/epitaxy/
VIGO Systems	Poland	MCT	http://www.vigo.com.pl/about-us
Research Institute No. 11	China	MCT	
Kunming Institute of Physics	China	MCT, T2SL, QWIP	http://dx.doi.org/10.1117/12.2034514
IRnova AB	Sweden	QWIP	http://www.ir-nova.se/manufacturing/
i3 Systems	South Korea	MCT, InSb	http://www.i3system.com/eng/n_about/introduction.html
NICT	Japan	T2SL	http://www.nict.go.jp/en/
Sumitomo	Japan	T2SL	http://global-sei.com/sc/products_e/epi/index.html
Pulsar, Orion R&P	Russia	MCT, QWIP?	http://www.orion-ir.ru/
Sofradir	France	InGaAs, QWIP, MCT, InSb	http://www.sofradir.com/
Fujitsu Laboratories	Japan	MCT	http://adsabs.harvard.edu/abs/1992JCrGr.117...24T
Semi-Conductor Devices (SCD)	Israel	InSb, T2SL, MCT, XBN	http://www.scd.co.il/SCD/Templates/showpage.asp?DBID=1&LNGID=1&TMID=84&FID=1310
Selex	UK, Italy	MCT	http://www.selex-es.com/product-portfolio/optronics-system/thermal-detectors
AIM Infrarot	Germany	MCT	http://www.aim-ir.com/en/main/company-profile/core-competencies-technologies-research-development.html
Aselsan	Turkey	QWIP, MCT	http://www.aselsan.com.tr/en-us/capabilities/electro-optic-systems
Chungwha	Taiwan	InGaAs	http://www.leadinglight.com.tw/03services01.html
Xenics	Belgium	InGaAs	http://www.xenics.com/en/custom-engineering
13 North Night Vision Technology Co.,Ltd.	China	MCT and more	http://en.norincogroup.com.cn/html/2012/memberunit_0320/29.html
Hamamatsu	Japan	InGaAs	http://www.hamamatsu.com/us/en/product/alpha/I/4007/4002/4107/index.html
III-Vlab	France	QWIP, T2SL, InGaAs	http://www.3-5lab.fr/services.htm
Universities (there are many more with EPI wafer growing capabilities WW…)			
Beijing University of Technology	China	T2SL	http://english.bit.edu.cn/
Shanghai Institute of Microsystem and Information Technology	China	QWIP, T2SL	http://english.sim.cas.cn/rs/fs/
Chalmers University of Technology	Sweden	T2SL	http://www.chalmers.se/en/departments/mc2/laboratories/NFL/Pages/default.aspx
Université Montpellier	France	T2SL	http://www.umontpellier.fr/
Military University of Technology	Poland		http://www.ztl.wat.edu.pl/zoplzm/docs/IOE.htm
University of Sheffield	UK		http://www.sheffield.ac.uk/eee/research/smd
LETI	France	QWIP, T2SL	
METU	Turkey	QWIP, InGaAs, MCT	http://www.eee.metu.edu.tr/~besikci/group/index.html
KAIST	South Korea	MCT, InSb	

HOT HERCULES

1280 X 1024, 15 μm pitch, Digital XBn MWIR

Designed for 24/7 Operation





Description

HERCULES is a Mega-Pixel IR detector, which is now available at high operating temperature.
HOT Hercules is based on SCD's latest FPA technology which enables a very high FPA operating temperature of 150K without compromising on detector performance.
This results with reduced SWaP (Size, Weight and Power) and high reliability of more than 20,000 hours.
This is achieved by the combination of an advanced IR detectors manufacturing technologies available today:

- 15 μm pitch XBn technology (150K operation)
- Digital ROIC - 0.18 μm Si-CMOS
- Compact, Stiff Dewar
- Compact and light Integral rotary Stirling cooler

Applications

- IRST
- MWS
- Long Range Surveillance
- 24/7 Applications
- Navigation Payloads
- Reconnaissance

Main Features:

- 100 Hz Frame Rate at full window
- Long-term NUC stability
- **Digital output** with Camera Link interface
- High image quality
- Reduced component volume and power consumption
- High Reliability

SemiConductor Devices

Typical Performances

PARAMETER	PERFORMANCE
Detector type	XBn
Array Format	1280×1024
Focal Plane Temperature	150K
FPA spectral range	3.6 ÷ 4.2μm *
Pixel Pitch	15μm
Integration modes	ITR/IWR
Pixel capacity and Floor noise (FN)	6Me- (900e-); 1Me- (250e-)
Maximum frame rate @ 14 BIT resolution	100 F/S @ Full window
Digital resolution	Up to 15bit
Readout mode	Normal/ Dilution
Windowing	Flexible: at 2 row steps
Readout direction	Up-down, left-right
NETD	20mK@50% well fill capacity
Residual Non Uniformity	<0.04% STD/DR@10-90% well fill capacity
Cooler	Ricor K508/K508N or similar, 0.5W cooling power
Cooler MTTFF	> 20,000 hours
Operation Temperature	-40°C ÷ 71°C
Storage Temperature	-54°C ÷ 80°C
Dimensions (with Ricor K508N)	Weight - ~ 750 gr. Length (optical axis) - 149 mm

* Cut-on is filter dependent

SCD/UNC/45243-0314

SemiConductor Devices

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IPG PHOTONICS®

July 6, 2015

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

IPG Photonics Corporation appreciates the opportunity to comment on the proposed changes to the Category XII of the U.S. Munitions List ("USML").

1. IPG Photonics Background

IPG Photonics Corporation ("IPG") is the leading developer and manufacturer of a broad line of high-performance fiber lasers, fiber amplifiers and diode lasers used for diverse applications, primarily in materials processing. Key materials processing includes cutting, welding drilling, marking, engraving, brazing, annealing and 3D additive manufacturing. Fiber lasers are a relatively new generation of lasers that combine the advantages of semiconductor diodes, such as long life and high efficiency, with the high amplification and precise beam qualities of specialty optical fibers to deliver superior performance, reliability and usability.

A substantial majority of our products are used in materials processing applications (95.0% of sales in 2014), but our products are also used in advanced/research (3.3%), communications (1.1%) and medical applications (0.6%). We sell our products globally to original equipment manufacturers ("OEMs"), system integrators and end users. IPG markets its products internationally primarily through our direct sales force in Europe and Asia.

Headquartered in Oxford, Massachusetts, IPG (NASDAQ listed: IPGP) had net sales of $770 million in 2014, and employs over 3,000. In Oxford, Massachusetts, we employ approximately 1,000 in manufacturing, research and development, assembly and administrative capacities. In addition, IPG has research and development facilities in Birmingham, Alabama, Mountain View, California, Santa Clara, California, and Holmdel, New Jersey. IPG exports its products internationally from the United States. For more information, visit www.ipgphotonics.com.

IPG Photonics Corporation
50 Old Webster Road, Oxford, MA 01540 T. 508.373.1100 F. 508.373.1101
www.ipgphotonics.com

2. IPG Products and Customers

Our laser products include low (1 to 99 watts), medium (100 to 999 watts) and high (1,000 to 100,000 watts) output power lasers from 300 to 4,500 nm in output wavelength. These lasers either may be continuous wave (CW), quasi-CW (QCW) or pulsed. We offer several different types of lasers, which are defined by the type of gain medium they use: ytterbium, erbium and thulium, as well as Raman and hybrid fiber-crystal lasers.

Our amplifier products range from milliwatts to up to 1,500 watts of output power from 1,000 to 2,000 nm in output wavelength. We offer erbium-doped fiber amplifiers, Raman amplifiers and integrated communications systems that incorporate our amplifiers. These products are predominantly deployed in broadband networks such as fiber to the home, fiber to the curb, and passive optical networks, and dense wavelength division multiplexing, networks.

IPG also develops and sells specialized fiber laser systems for unique material processing applications, including remote welding, micro-welding and cutting, and annealing, which are also commercial manufacturing applications.

Well over 95% of IPG sales are for non-military applications. Our largest customer in 2014 was Han's Laser, a PRC-based maker of laser cutting, welding, marking and engraving systems for the Chinese metal processing market. Other IPG customers include BMW, GM, Ford, Chrysler, large Japanese auto maker, GE, Gillette, Foxconn, Bystronic, MAZAK, Philips, Mitsubishi Heavy Industries, Boeing and Pratt & Whitney.

3. Comments on Proposed Category XII

IPG's principal concern is that the proposed changes to USML Category XII would inadvertently control items that are currently in normal commercial use and that the proposal does not have thresholds that clearly delineate military and non-military products. Our comments are set forth below in further detail.

Paragraph (b) controls "lasers and laser systems and equipment" set forth in paragraphs (1) to (14). The introduction to paragraph (b) is ambiguous in whether the laser source (component) is controlled in paragraphs (1) to (8) or only the laser system or equipment in described in paragraphs (1) to (8). If the intent is control all laser sources that may be used in the items described in paragraphs (1) to (8), the USML would inadvertently control items that are not controlled on the Wassenaar Arrangement's Dual Use or Munitions Lists, plus items that are controlled on the Wassenaar Arrangement's Dual Use List that are in normal commercial use. Further, these laser sources are widely available from foreign sources in China and Israel as well as Wassenaar Agreement states as detailed below and in the Exhibits to this letter.

Lasers are general purpose light sources that can be used in various applications. Their use depends upon their wavelengths, the output power of the laser, the quality of the laser light, and if the light is continuous or pulsed. Often, commercial laser sources are used in military systems without special design, configuration or modification, as the U.S. military seeks out commercial off-the-shelf commodities to reduce its spending. On a stand-alone basis (i.e., not part of a laser system or laser equipment), laser sources are ineffective in either commercial or military contexts. The laser systems and laser equipment provide the necessary controls, output optics and feedback mechanisms necessary to achieve the specific purpose of the system or equipment.

Should the intent of the proposal be to control laser sources (i.e., components) under paragraphs (b)(1), (b)(2), (b)(3) or (b)(5) as part of laser target designator, aiming or target illumination system or equipment having laser output wavelength greater than 710 nm or a laser rangefinder with a Q-switched laser or laser output greater than 1,000 nm, then the proposal would control virtually all of IPG's materials processing laser product line used in commercial applications, as well as a substantial majority of lasers used in industrial production. The proposal could have the effect of putting a substantial majority of industrial lasers under control of the USML. CO_2 lasers typically emit near 10,600 nm output wavelength, and most Nd:YAG, fiber and diode laser used in industrial applications operate at output wavelengths greater than 710 nm. World-wide sales of industrial laser sources in 2014 covered by the Category XII proposal exceed $2 billion. A significant amount of these laser sources are manufactured by U.S. – based companies.

LASER	2013	2014	%	2015	%
CARBON DIOXIDE	863	884	2	877	-1
SOLID-STATE	456	444	-3	431	-3
FIBER	841	960	14	1085	13
OTHER	327	343	5	366	7
TOTAL	2487	2631	6	2759	5

Source: Industrial Laser Solutions, 1/26/2015. www.industrial-lasers.com.

IPG derives more than 95% of its revenue from lasers sources operating near 1,000 nm output wavelength, sold for laser systems used in cutting, welding, drilling, marking, engraving, brazing, annealing and 3D additive manufacturing. Q-Switched lasers with output exceeding 1,000 nm wavelength are ubiquitous in marking and engraving systems for metals and plastics, such as parts and electronics. Lasers sold in 2014 for marking and engraving worldwide exceeded

$347 million with a substantial majority of laser sources operating at 710 nm wavelength or greater, Source: Industrial Laser Solutions, 1/26/2015. www.industrial-lasers.com.

IPG manufactured over 20,000 lasers in 2014 for non-military application with output wavelength exceeding 710 nm. See Exhibit A for IPG data sheets and applications selection guide for laser sources exceeding 710 nm output wavelength. The data sheets for these families clearly show that the IPG products are designed for non-military applications.

Further, there is substantial foreign availability of Q-Switched lasers sources and laser sources with output wavelengths exceeding 710 nm from China and Israel, in addition to the Wassenaar states. See Exhibit B for a partial listing of non-Wassenaar availability of fiber lasers that would be covered by these entries (b)(1), (b)(2) or (b)(3). Examples of foreign availability include:

- V-Gen (Tel Aviv, Israel) manufactures industrial Q-Switched fiber lasers up to 100 W average power with output wavelength exceeding 1,000 nm;
- Raycus Laser (Wuhan, China) manufactures Q-Switched fiber lasers up to 100W average power and continuous wave fiber lasers up to 10,000 W average power, both with output wavelength exceeding 1,000 nm; and
- Max Photonics (Shenzhen, China) manufactures Q-Switched fiber lasers up to 100 W average power and continuous wave fiber lasers up to 6,000 W average power, both with output wavelength exceeding 1,000 nm.

Two Chinese manufacturers Raycus and Max Photonics, are estimated to have sold over 15,000 pulsed lasers operating near 1,000 nm operating wavelength in 2014 for marking and engraving applications.

In addition, laser sources manufactured in Wassenaar states include:

- Trumpf Laser (Ditzingen, Germany) and Rofin-Sinar Laser GmbH (Hamburg/Munch, Germany) both make fiber and non-fiber lasers exceeding 710 nm and Q-Switched lasers that meet the parameters in entries (b)(2) and (b)(3). Representative data sheets from their product lines are also in Exhibit B.
- IPG also manufactures most of its commercial lasers and amplifier lines in its European facilities.

IPG would be adversely affected in competing in global industrial laser system markets if paragraphs (b)(1) to (b)(8) are intended to cover all laser sources with output wavelength exceeding 710 nm and all Q-Switched laser sources. Were

IPG or other industrial laser makers in the United States required to obtain State Department licenses to export the commercial lasers now controlled under the Wassenaar Arrangement Dual Use List, it would create an environment in which the U.S. manufacturers would not be able to compete globally, strengthening foreign-based laser makers. As IPG also manufactures its commercial products abroad, controlling these products on the USML could result in a shift production outside of the United States and a loss manufacturing capacity and technological expertise in the United States. As these lasers are in such widespread commercial use world-wide, it is difficult to see how such laser sources provide the United States with critical military or intelligence advantages.

The laser sources that could possibly be used in the lasers described in paragraphs (b)(1) to (b)(8) include the workhorses of industrial laser systems: Nd:YAG lasers, fiber lasers, diode and CO_2 lasers. While some may be controlled under Category 6 of the Wassenaar Arrangement Dual Use List, many are not controlled at all because they do not have the requisite output power or beam quality commonly used in the Category 6 laser controls to distinguish between non-dual use and dual use commodities.

We further note that paragraphs (b)(1) to (b)(8) contain no laser parameter other than (1) output wavelength exceeding 710 nm in (b)(2) and (b)(5) and (2) Q-Switched or output wavelength exceeding 1,000 nm in (b)(3). Because the lasers described in paragraphs (b)(1) to (b)(8) are so widely used in non-military applications, we believe that these parameters do not limit the control to military lasers. As written, paragraphs (b)(1) to (b)(8) will capture commercial lasers. In addition, the proposed controlling parameter of "Q-Switched laser pulse" in (b)(3)(i) would arguably cover every type and power of pulsed lasers. Category 6 of the Wassenaar Dual Use List employs additional parameters to define dual use items such as power levels, beam quality, pulse speed and peak power. At a minimum, the paragraphs should be redrafted with the parameters of the laser to establish the missing "bright line" between USML and the dual use lists.

Unlike paragraphs (b)(1) to (b)(8), paragraphs (b)(9) to(b)(13) clearly specify that the laser source is the controlled item and provide more than one laser parameter. Paragraphs (b)(9) to (b)(13) are unambiguous in their application to the laser source (component).

We believe that the intent of paragraph (b) of proposed Category XII is to control the equipment or system (i.e., laser target designator or laser range finder) and not the laser source (component) that may provide the light for the systems and equipment controlled in paragraphs (b)(1) to(b)(8). We also believe that laser sources specially designed for equipment or systems listed in paragraphs (b)(1) to (b)(8) are controlled by paragraph (e)(13) of the proposed Category XII. Paragraph (e)(13) controls "resonators, ...gain media... or frequency converters specially designed for laser systems or equipment controlled by this category." Accordingly, we suggest removing the ambiguity by omitting the words "Lasers and laser systems and equipment, as follows" from the lead-in to paragraph (b) as it creates uncertainty and may lead to control of commercial laser sources unintentionally. In the alternative, consider applying to paragraph (b) the "specially designed" criteria as defined in Section 120.41 of the USML.

Paragraphs (b)(1) and (b)(2), laser target designator or coded target market, are vague and have no parameters for the system or equipment in terms of performance. Also, the term "target" used in both paragraphs can have different meanings in non-military contexts. For example, the term "target" is used sometimes in the scanning of objects in commercial applications,. The item scanned can be referred to as a "target" in such commercial systems. We suggest that these paragraphs be revised to add appropriate parameters to establish a "bright line" between defense articles on the USML and non-military scanning systems.

Paragraph (b)(3) covers laser rangefinders having any of the following (1) a Q-switched laser pulse or (2) laser output wavelength exceeding 1,000 nm. Laser rangefinders are common in many non-military application, including sports (e.g., golf, hunting and archery), 3-D modeling and manufacturing, forestry, and laser measurement tools. Many of these use eye-safe wavelengths (near 1550 nm). Even sport range finders could fall under the current Category XII proposal. A rewrite of paragraph (b)(3) should contain the specifications in laser range finders that provide the United States with critical military or intelligence advantage.

Paragraph (b)(8) controls LIDAR, LADAR or other laser range-gated systems having a resolution of 0.2 m or less from an altitude above ground level greater than 16,500 ft. We believe that the proposal is based upon the current limits of today's commercial performance rather than defining parameters of military significance. A commercial surveying system near the limits proposed is the Leica ALS-80, an airborne LIDAR designed for general purpose urban, flood plain, ore general-purpose mapping. The datasheet for the Leica system can be found at http://www.leica-geosystems.com/downloads123/zz/airborne/ALS80/brochures/Leica%20ALS80%20BRO_en.pdf

Paragraph (b)(14) controls developmental lasers and laser systems or equipment funded by the Department of Defense. Other than set forth in the notes to paragraph (b)(14), the proposal applies to all lasers even though the laser may not be for or part of fire control, range finder, optical and guidance control equipment. For example, this section would control laser or laser equipment for paint stripping or laser cleaning or a laser for dental treatment, if funded by the Department of Defense. The title of Category XII is Fire Control, Range Finder, Optical and Guidance Control Equipment. The proposed coverage of paragraph (b)(14) goes far beyond the subject matter of Category XII by controlling <u>all</u> lasers, laser systems and equipment funded by the Department of Defense even if they are not for or related to fire control, range finding, optical and guidance and control equipment which are the object of Category XII. Category XII does not purport to control all lasers and laser systems or equipment. We suggest that the entry be limited to the enumerated items in paragraph (b) rather than all lasers, laser systems or equipment funded by the Department of Defense.

Also, the application of paragraph (b)(14) in Category XII may overlap paragraph (f) in recently proposed Category XVIII, Directed Energy, as some directed energy weapons include lasers. This further supports limiting the language of paragraph (b)(14) to the items in Category XII paragraph (b) rather than all lasers, laser systems and equipment.

4. Conclusion

IPG urges the Secretary of Commerce, Secretary of State, and Secretary of Defense to fundamentally rewrite the proposed rule before it is finalized. Additionally, a rewritten Category XII should fully implement the "specially designed" criteria to ensure that products with commercially applications are placed on the Commerce Control List (CCL), as opposed to the USML. The "specially designed" criteria as defined in §120.41 of the USML, should be applied fully to Category XII. The Department of Defense and the Department of Commerce agreed upon a definition and on October 15, 2013, the "specially designed" definition was finalized. Subsequently, this criteria was applied to USML categories as they were individually revised in the ECR process. However, in the Category XII proposal, the use of "specially designed" is limited. Instead, no criteria are proposed in many cases that are based on the limits of today's commercial performance for these items rather than defining parameters of military significance. The proposal for Category XII would regulate companies to performance parameters that are below or near the edge of today's commercial market, as opposed to defining parameters of military sensitive items.

Additionally, the munitions list should also align with the internationally agreed upon Wassenaar Munitions List. Commodities and components not specially designed for military purposes or on the Wassenaar Munitions List should be controlled under the CCL. IPG, like many companies, manufactures the same products abroad as they do in the United States and controlling them differently in the United States via a broader USML will result in loss of capacity to manufacture in the United States. Though still controlled under the CCL, the list controlled by the Department of Commerce allows for more flexibility on how controls are applied, and can adjust to conditions more quickly than items under the USML.

Thank you for this opportunity to comment on the proposed changes to the Category XII of the USML. If you would like to discuss this letter further or need other information, please contact me at 508-373-1123 or alopresti@ipgphotonics.com.

Sincerely,

IPG Photonics Corporation

Angelo P. Lopresti
Senior Vice President, General Counsel and Secretary

Enclosures:

Exhibit A: IPG Product Families and Applications

Exhibit B: Foreign Availability

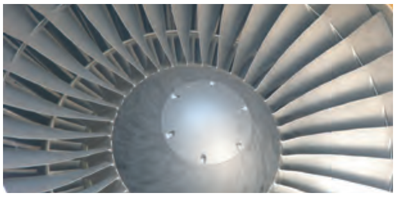
Exhibit A

IPG Product Families for Commercial Applications

Industrial Fiber Lasers for Materials Processing

from the World Leader in Fiber Lasers

PRODUCT GUIDE



Applications

Features

Efficiency

Capabilities

www.ipgphotonics.com

The Power to Transform®

FIBER LASER ADVANTAGES

What you can expect from an IPG Fiber Laser

IPG Photonics Corporation is the world leader in high power fiber lasers and amplifiers. Founded in 1990, IPG pioneered the development and commercialization of optical fiber-based lasers for use in a wide range of venues such as materials processing, telecom, medical, scientific and other advanced applications. Fiber lasers have revolutionized the industry by delivering superior performance, reliability and usability at a lower total cost of ownership compared with conventional lasers, allowing end users to increase productivity and decrease operating costs.

IPG is the only company that controls the performance, cost and yield of both active fibers and semiconductor pump diodes- the core technology of the fiber laser. IPG develops and manufactures process fibers, beam couplers and switches, collimators, chillers and most recently processing heads and fully custom laser systems. This innovation, coupled with extensive manufacturing capabilities, place IPG in the rare position of being in full control of every step needed to achieve this mission: to deliver innovative, reliable, high quality and high performance fiber lasers at a cost-effective price.

The product of this mission is exemplified best through IPG's most popular laser family, the YLS Series. Ranging in power from 500 W to 100 kW, operating in CW or modulated modes up to 20 kHz with wall-plug efficiencies greater than 30%, the dynamic operating range of these devices is available from 10% to full power with no change in beam divergence or beam profile throughout the entire range. This allows a single laser to be utilized for both high and low power applications such as welding, drilling and precision cutting, a previously unheard of capability. IPG lasers' divergence specifications are far superior than other lasers and allow the use of long focal length processing lenses for vastly improved depth of field, less damage to optical components and are ideal for remote applications.

Fiber lasers deliver their energy through an integrated flexible optical fiber. Fiber lasers have a monolithic, entirely solid state, fiber-to-fiber design that does not require mirrors or optics to align or adjust. These features make fiber lasers easier to integrate and operate in production, medical and other laser-based systems. Fiber lasers are typically smaller and lighter in weight than traditional lasers, saving valuable floor space. While conventional lasers can be delicate due to the precise alignment of mirrors, fiber lasers are more rugged and able to perform in variable working environments. These qualities permit fiber laser systems to be transported easily.

IPG is headquartered in Oxford, Massachusetts with additional manufacturing plants, sales and service offices throughout the world.

MAIN FEATURES

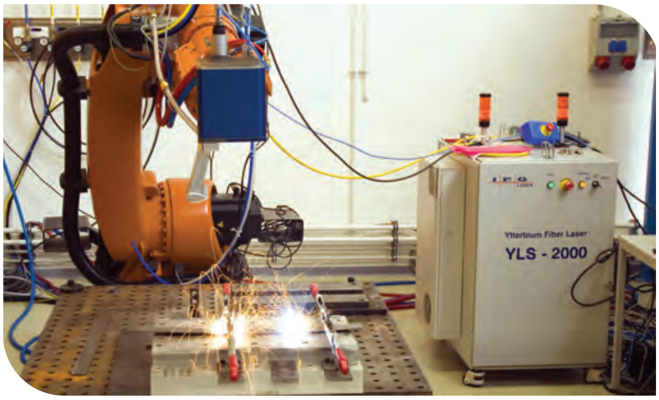
- Excellent Beam Parameter Product (BPP)
- Constant BPP Over Entire Power Range
- Small Focus over Large Working Distance
- Over 30% Wall-plug Efficiency
- Maintenance-free Operation
- Modular 'Plug & Play' Design
- Compact, Rugged & Easy to Install
- Integrated Coupler or Beam Switch

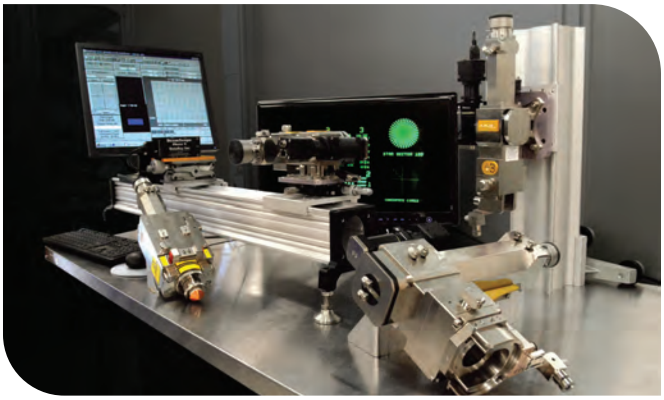
FIBER LASER FAMILIES

A Diverse Range for a Multitude of Applications

LASERS

ACCESSORIES





APPLICATION GUIDE	YLS	YLR	QCW	GLR	GLP	TLR	YLP
Ablation					○		○
Annealing	○			○			
Brazing	○						
Cladding	○						
Cutting	○	○	○	○	○		○
Deep Engraving				○	○		○
Drilling	○		○		○		○
Heat Treating	○						
Marking				○	○	○	○
Soldering		○		○			
Welding	○	○	○	○		○	

YLS SERIES

High Power CW Ytterbium Fiber Laser Systems

Applications

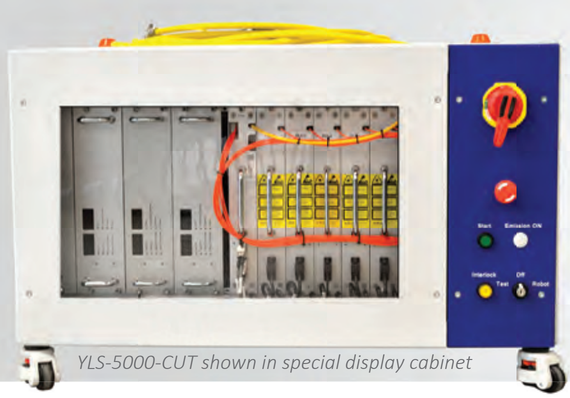
- Annealing
- Brazing
- Cladding
- Cutting
- Drilling
- Heat Treating
- Welding

Efficiency

- > 30% Wall-plug Efficiency (WPE)
- 40% WPE on ECO Series
- Industry Leading Diode Lifetime

Capabilities

- Plug & Play Design
- Compact, Rugged & Efficient
- Output Power up to 100 kWs



YLS-5000-CUT shown in special display cabinet

Standard Features

The YLS series fiber laser, with output powers up to 100 kW, was developed as a complete system for industrial applications. They have garnered wide acceptance in the very demanding automotive, aerospace and oil and gas industries. All YLS systems are housed in a NEMA 12, air-conditioned and sealed cabinets adding to the robustness of the unit. These systems are controlled by either digital I/O, analog control or IPG's own LaserNet software with the additional option to add either DeviceNet, Profibus or Ethernet interfaces. Developed as a complete system, this design features the widest range of fiber diameters, as well as the option to terminate to up to 6 ports from one power source.

YLS LASER CONFIGURATIONS

Single-output Identifiers

1 kW	2 kW	3 kW	4 kW	5 kW	6 kW	7 kW - 10 kW

YLS Basic

The YLS Basic fiber laser is available in up to 10 kW single-mode and 100 kW multi-mode output power. The Basic has a direct feeding fiber terminating in either an HLC-8 (QBH-type) or LCA (QD-style) connector in standard lengths of up to 30 meters.

1 kW	2 kW	3 kW	4 kW	5 kW	6 kW	7 kW - 10 kW
○ YLS-1000	○ YLS-2000	● YLS-3000	● YLS-4000	● YLS-5000	● YLS-6000	● YLS-7000... YLS-10000
50 µm feed standard, also available in either 100 or 200 µm diameter.				100 µm standard, also available in 50 or 200 µm diameter.		100 µm feed standard 200 µm diameter available

YLS-CUT

IPG's family of kW class CUT lasers are specifically designed for high performance in harsh cutting environments. The CUT series features a super compact design with the laser housed in an hermetically sealed cabinet. A dehumidifier is installed within the cabinet to ensure optimal internal humidity. The lasers have a wall-plug efficiency of over 35%, so the electrical cost savings our lasers are famous for continues to improve. Hot redundancy ensures 100% up time with no change in power, ensuring record reliability and maintenance free operation. The CUT series are available from 1-6 kW with a wide variety of fiber delivery options, starting at 50 µm core diameter.

1 kW	2 kW	3 kW	4 kW	5 kW	6 kW	7 kW - 10 kW
● YLS-1000-CUT	● YLS-2000-CUT	● YLS-3000-CUT	● YLS-4000-CUT	● YLS-5000-CUT		
50 µm feed standard, also available in either 100 or 200 µm diameter.						

NEW!

YLS-ECO

IPG Photonics' YLS-ECO family is a new generation of kW class low-mode Ytterbium fiber lasers with record wall-plug efficiency of over 40%. IPG's Eco series offers a new, unparalled level of reliability. The ECO series is perfectly suited for applications that cannot tolerate any downtime or service intervention.

1 kW	2 kW	3 kW	4 kW	5 kW	6 kW	7 kW - 10 kW
○ YLS-1000-ECO	○ YLS-2000-ECO	● YLS-3000-ECO	● YLS-4000-ECO	● YLS-5000-ECO	● YLS-6000-ECO	
50 µm feed standard, also available in either 100 or 200 µm diameter.				100 µm standard, also available in 50 or 200 µm diameter.		

CABINET SIZE DENOTED BY COLOR

- ○ 12U NEMA 12 Enclosure H x W x D, 558 x 790 x 815 mm
- ● 12U Extended NEMA 12 Enclosure H x W x D, XXX x 790 x 815 mm
- ● 25U NEMA 12 enclosure H x W x D, 1186 x 856 x 806 mm
- ● 31U NEMA 12 Enclosure H x W x D, 1482 x 856 x 806 mm
- ● 31U NEMA 12 w/ Side Cabinet H x W x D, 1490 x 1480 x 810 mm

Multiple Fiber Outputs: *Options & Features*

The YLS laser also features the option to terminate up to six ports from one power source. Delivery optics up to four ports can be housed inside the main laser cabinet, with six ports available in a separate NEMA 12 housing for safety and enhanced mobilty. IPG develops and manufactures all delivery optics in-house which allows for fast lead times and enhanced in-house support. Available options include couplers, beam shutters, beam switches and shearers in D12.5, D25 and D50 diameters; see page 11 for available optics.

Multi-output Capabilities

- Up to 6 Ports for Simultaneous or Alternating Work Cells
- Process Fibers Available in up to 1 µ dia.
- 100 % Beam Switching or Variable Beam Shearing Available
- Beam Dump on Switches
- Multi-application use from one Laser

YLS LASER CONFIGURATIONS

Multi-output Identifiers

	1 kW	2 kW	3 kW	4 kW	5 kW	6 kW	7 kW - 10 kW
	50 µm feed standard, also available in either 100 or 200 µm diameter.			100 µm standard, also available in 50 or 200 µm diameter.			100 µm feed standard 200 µm diameter available
YLS with Internal Coupler: Internal 1" coupler. Allows for a multitude of passive fiber lengths & widths. Provides extra protection if fiber damage occurs.	YLS-1000-CT	YLS-2000-CT	YLS-3000-CT	YLS-4000-CT	YLS-5000-CT	YLS-6000-CT	YLS-7000-C... YLS-10000-C
YLS with Internal Beam Shutter Internal 1" shutter. Allows for a multitude of passive fiber lengths & widths. Provides extra protection as well as faster on/off.	YLS-1000-S1T	YLS-2000-S1T	YLS-3000-S1T	YLS-4000-S1T	YLS-5000-S1T	YLS-6000-S1T	YLS-7000-S1... YLS-10000-S1
YLS with Internal Beam Switch Internal beam switching, D50. Allows for multi-station and application processing. Part numbers for 2, 3 and 4 way switches shown below.	YLS-1000-S2T YLS-1000-S3T YLS-1000-S4T	YLS-2000-S2T YLS-2000-S3T YLS-2000-S4T	YLS-3000-S2T YLS-3000-S3T YLS-3000-S4T	YLS-4000-S2T YLS-4000-S3T YLS-4000-S4T	YLS-5000-S2T YLS-5000-S3T YLS-5000-S4T	YLS-6000-S2T YLS-6000-S3T YLS-6000-S4T	YLS-7000-S2... YLS-8000-S3 YLS-10000-S4
YLS with Internal Beam Shearer 2-way beam shearer, D50, 50:50 split. For simultaneous operation of 2 stations each at 50% power. (Four port option also available with switching in ports A/B & C/D shearing, "SS4T" suffix.	YLS-1000-SS2T	YLS-2000-SS2T	YLS-3000-SS2T	YLS-4000-SS2T	YLS-5000-SS2T	YLS-6000-SS2T	YLS-7000-SS2... YLS-10000-SS2
YLS-Tropical YLS System with an affixed chiller. Only available for certain output powers and configurations. Note: 31U with side cabinet required for 4 - 6 kW units.	YLS-1000-TR YLS-1000-CUT-TR YLS-1000-CT-TR YLS-1000-S2T-TR YLS-1000-S3T-TR YLS-1000-S4T-TR YLS-1000-SS2T-TR	YLS-2000-TR YLS-2000-CUT-TR YLS-2000-CT-TR YLS-2000-S2T-TR YLS-2000-S3T-TR YLS-2000-S4T-TR YLS-2000-SS2T-TR		YLS-4000-S2-TR YLS-4000-S3-TR YLS-4000-S4-TR YLS-4000-SS2-TR	YLS-5000-C-TR YLS-5000-S2-TR YLS-5000-S3-TR YLS-5000-S4-TR YLS-5000-SS2-TR	YLS-6000-C-TR YLS-6000-S2-TR YLS-6000-S3-TR YLS-6000-S4-TR YLS-6000-SS2-TR	

Part numbers, configurations, and availability subject to change.

YLR SERIES

Rack Mounted CW Ytterbium Fiber Lasers

YLR LASER CONFIGURATIONS

Applications

- Cutting
- Drilling
- Soldering
- Welding

Efficiency

- Over 30% Wall-plug Efficiency
- Industry Leading Diode Lifetime

Capabilities

- Pulse Modulation
- Plug & Play Design
- Multi port options available
- Compact, Rugged & Efficient

Standard Features

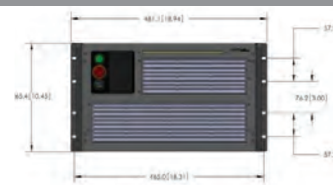
IPG's YLR Series represents a new generation of diode-pumped CW fiber lasers of near infrared spectral range (1060-1080 nm) with a unique combination of high power, ideal beam quality, fiber delivery and high wall-plug efficiency. The YLR laser is offered as a cost-effective, adaptable solution for a clean room system or for integration into a production line. Featuring a front panel touch-screen display or rear control via Analog, RS-232, or Ethernet interfaces, the rack mount configuration is ideal for a multitude of applications from cutting, welding and drilling to medical device manufacturing.

Features Output powers up to 1 kW water-cooled (WC) with air-cooled (AC) models up to 500 Watts.
IPG D12.5 external delivery optics are available for the YLR Series (see page 5).

YLR LASER PART NUMBERS

CABINET SIZE DENOTED BY GRADIENT

3U 19" rack W 448 x D 403 x H 132	4U 19" Rack W 449 x D 503 x H 177	6U 19" Rack W 448 x D 502 x H 266



OUTPUT POWER (WATTS)

100 W | 200 W | 300 W | 400 W | 500 W | 600 W | 700 W | 1,000 W

Multi-mode YLR

100 to 1,000 W lasers equipped with a standard 50 µm feeding fiber to HLC-8 connector. Additional options include 100 or 200 µm diameters to HLC-8 connector or 50, 100 or 200 µm to an affixed collimator. Available focal lengths: 20, 38 or 53 mm.

100 W	200 W	300 W	400 W	500 W	600 W	700 W	1,000 W
YLR-100-MM-AC	YLR-200-MM-AC	YLR-300-MM-AC	YLR-400-MM-AC	YLR-500-MM-AC			
YLR-100-MM-WC	YLR-200-MM-WC	YLR-300-MM-WC	YLR-400-MM-WC	YLR-500-MM-WC	YLR-600-MM-WC	YLR-700-MM-WC	YLR-1000-MM-WC

50 µm feed fiber to HLC-8 Connector

Single-mode YLR

100 to 1,000 W lasers equipped with a 5 mm beam diameter affixed collimator for powers up to 400 Watts; 500- 1,000 Watt lasers terminate to an HLC-8 connector. Interchangeable collimators and processing heads connect easily to the HLC-8, options listed on page 9. Affixed collimator options include beam diameters in either 2.5 or 7.5 mm.

100 W	200 W	300 W	400 W	500 W	600 W	700 W	1,000 W
YLR-100-AC	YLR-200-AC	YLR-300-AC	YLR-400-AC	YLR-500-AC			
YLR-100-WC	YLR-200-WC	YLR-300-WC	YLR-400-WC	YLR-500-WC	YLR-600-WC	YLR-700-WC	YLR-1000-WC

Single-mode feed fiber to Affixed Collimator (5 mm beam diameter) | Single-mode feed fiber to HLC-8 Connector

ELR, TLM & TLR LASER CONFIGURATIONS

Erbium or Thulium lasers are also available in a rack design, available models listed below. Green (532 nm) offerings can be found on page 8.
The Erbium fiber laser (ELR Series), operating in the 1530-1620 nm "eye-safe" wavelength with output powers up to 200 Watts, is a unique instrument that provides a diffraction-limited, high-power CW light source. Typical industrial applications include plastic and polymer welding.
AVAILABLE MODELS: Single-mode: ELR-20-AC, ELR-30-AC, ELR-50-AC, & ELR-50-WC

The Thulium fiber laser (TLR Series), operating in the 1900-2050 nm wavelength range, offers output powers up to 120 Watts. Typical industrial applications include plastic cutting and marking, non-metal materials processing and solid state IR laser pumping.
AVAILABLE MODELS: Single-mode: TLR-50-AC, TLM-50- WC, TLR-100-AC, TLM-100-WC
Multi-mode: TLR-50-MM-AC, TLM-50-MM-WC, TLR-100-MM-AC, TLM-100-MM-WC, TLR-200-MM-WC

QCW SERIES

Quasi-CW Ytterbium Fiber Lasers

QCW LASER CONFIGURATIONS

Applications

- Cutting
- Drilling
- Welding

Efficiency

- Over 30% Wall Plug Efficiency
- Industry Leading Diode Lifetime

Capabilities

- Long Pulse Operation
- Plug & Play Design
- Maintenance-free Design

Standard Features

Quasi-continuous wave (QCW) fiber lasers are ideally suited for numerous industrial applications requiring a long pulse duration and high peak power such as spot welding, seam welding and drilling. Designed to displace existing YAG lasers due to their minimal maintenance costs and low upfront costs, the QCW is easily able to be retrofitted into most existing systems.

YLM Module

OEM Module design. Air-cooled cabinet with Analog/ RS-232/ and Ethernet control interfaces.

YLR Rackmount

Rack mountable housing. Air-cooled cabinet with touch-screen display. Analog/ RS-232/ and Ethernet interfaces included.

- 4U Rack
- 6U Rack

Dimensions available on page 6

YLS System

Ytterbium Fiber Laser System. Lasernet/ Analog/ RS-232/ and Ethernet interfaces included.

- Air-cooled NEMA Housing.
- Water-cooled NEMA 12 Housing.

QCW LASER PART NUMBERS	CW	PEAK	FEEDING FIBER	ENCLOSURE
	OUTPUT POWER (WATTS)			W X D X H (mm)
YLM-150/1500-QCW-AC	150 W	1,500 W	Single mode	OEM Module, 264 x 432 x 150
YLM-150/1500-QCW-MM-AC	150 W	1,500 W	50, 100 or 200 µm	OEM Module, 264 x 432 x 150
YLM-300/3000-QCW-MM-AC	300 W	1,500 W	50, 100 or 200 µm	OEM Module, 336 x 432 x 150
YLR-150/1500-QCW-AC	150 W	1,500 W	Single mode	4U Rack mount, 449 x 503 x 177
YLR-150/1500-MM-AC	150 W	1,500 W	50, 100 or 200 µm	4U Rack mount, 449 x 503 x 177
YLR-300/3000-QCW-MM-AC	300 W	3,000 W	50, 100 or 200 µm	6U Rack mount, 448 x 502 x 266
YLS-300/3000-QCW-AC	300 W	3,000 W	50, 100 or 200 µm	NEMA housing, 804 x 604 x 605
YLS-450/4500-QCW-AC	450 W	4,500 W	50, 100 or 200 µm	NEMA housing, 804 x 604 x 605
YLS-600/6000-QCW-AC	600 W	6,000 W	50, 100 or 200 µm	NEMA housing, 804 x 604 x 605
YLS-900/9000-QCW-WC	900 W	9,000 W	100, 200 or 300 µm	12U NEMA 12 Housing, 558 x 790 x 815
YLS-1200/12000-QCW-WC	1,200 W	12,000 W	100, 200 or 300 µm	12U wide NEMA 12 Housing, 1186 x 856 x 806
YLS-1500/15000-QCW-WC	1,500 W	15,000 W	100, 200 or 300 µm	12U wide NEMA 12 Housing, 1186 x 856 x 806
YLS-1800/18000-QCW-WC	1,800 W	18,000 W	100, 200 or 300 µm	12U wide NEMA 12 Housing, 1186 x 856 x 806
YLS-2000/20000-ACW-WC	2,000W	20,000W	100, 200 or 300 µm	12U wide NEMA 12 Housing, 1186 x 856 x 806

Part numbers, configurations, and availability subject to change.

Applications

- Ablating
- Deep Engraving
- Cutting
- Marking
- Texturing
- Surface Treatment

Efficiency

- Over 30% Wall-plug Efficiency
- Industry Leading Diode Lifetime

Capabilities

- High Peak Powers
- Large Range of Output Powers
- Maintenance-free Design

Standard Features

The YLP Series are maintenance-free MOPFA and Q-switched pulsed Ytterbium fiber lasers designed for OEM applications. Collimated, isolated and then typically focused to a spot size of a few microns or less, the near diffraction-limited beam can mark, drill or machine a variety of materials.

IPG's Q-switch fiber lasers are available in several different power ranges and pulse durations, with average powers up to 500 watts and peak powers up to 150 kilowatts. These compact fiber lasers feature low divergence and can provide the fluency required for high speed marking of both plastics and metals.

YLPN SERIES: NANOSECOND FIBER LASERS

IPG's nanosecond fiber lasers are the core products for most industrual materials processing needs. Available in a multitude of different configurations, output powers, pulse durations and terminations, the YLPN Series has the versatitity needed for multiple applications.

YLP-HP SERIES
High Power Q-switch fiber laser system. Rack mounted housing, front panel control. 1-10 mJ Pulse Energies. 6-9 mm beam diameter.

YLP SERIES
Basic Q-switch fiber laser module, high contrast, air-cooled. 0.5-1 mJ Pulse Energy. 6-7 mm beam diameter.

YLP-RA SERIES
Q-switch fiber laser module w/ remote amplifier. Air-cooled. 0.5-1 mJ Pulse Energy. 3-4.5 mm beam diameter

YLPM SERIES
Q-switch fiber laser module w/ selectable output, bitstream control and extended PRR. Air-cooled. 0.3-1 mJ Pulse Energy. 10 & 20 W: 6-9 mm beam, 18 W: 2 mm beam diameter

YLP-V2 SERIES
Q-switch fiber laser module with bitstream control and extended PRR and high contrast. Air-cooled. 1 mJ Pulse Energy. 6-9 mm beam diameter.

YLPP SERIES: PICOSECOND FIBER LASERS

IPG's short picosecond fiber lasers provide high peak power with scalable average output power of 30 W and short pulse duration of 10-20 ps at full operational frequency range of 20-3000 kHz. The all fiber format allows for the adjustment of peak power and/or pulse repetition rate without affecting any of the output beam parameters. It is ideal for applications in micromachining, solar/photovoltaic arena, via hole drilling, resistor trimming and marking of transparent materials.

YLPF SERIES: FEMTOSECOND FIBER LASERS

IPG Photonics' YLPF Series femtosecond fiber lasers provide high peak power with scalable average output power of 10 W, short pulse duration of 500 fs at full operational repetition rate range of 20-3000 kHz. The all fiber format allows for the adjustment of peak power and/or pulse repetition rate without affecting any of the output beam parameters. It is ideal for applications in ophthalmology, life sciences and precision micromachining.
The excellent beam quality, ultrashort pulse duration and high pulse energy combine to provide peak power densities suitable for micromachining virtually any material: metal, glass, ceramic, silicon, plastics. The ultrashort pulse duration results in very small heat affected zone.

NEW! NEW! **YLPN-50-120-4000-S**: MEGAPULSE YTTERBIUM LASER

IPG Photonics' new high power, pulsed fiber laser is designed with an average output power of 4 kW at the work piece, a pulse energy of 40 mj and a pulse duration of 120 ns. With a wall-plug efficiency of 30%, a variety of fiber delivery options, a small form factor and maintenance-free operation, IPG's new high power pulsed laser is ideally suited to surface preparation and treatment, laser ablation and laser surface cleaning- a process that can be carried out without abrasives, solvents and chemicals.

GREEN SERIES

CW & Pulsed 532 nm Fiber Lasers

GLR & GLP CONFIGURATIONS

Applications

CW/ QCW GREEN

- Annealing
- Additive Manufacturing
- Cutting
- Soldering
- Welding

PULSED GREEN

- Ablating
- Cutting
- Deep Engraving
- Drilling
- Marking

Efficiency

- Over 30% Wall-plug Efficiency
- Industry Leading Diode Lifetime

Capabilities

- High Brightness
- Compact & Efficient

Standard Features

Fiber Lasers in the green spectrum range enable IPG to serve new markets and applications. At output wavelengths of 532 nm, the new pulsed green fiber laser and continuous wave (CW) green fiber laser provide the high single-mode beam quality, ease of use and high reliability that IPG's fiber lasers are known to deliver at lower prices than competitive green lasers.

GLP Module

OEM Module design. Air cooled laser with Analog/ RS-232/ and Ethernet control interfaces. Single-mode free launch beam output.

Displayed on left.

GLR Rackmount

Rack mountable housing. Air-cooled cabinet with touch-screen display. Analog/ RS-232/ and Ethernet interfaces included. Single-mode free launch beam output.

Displayed above.

- 3U Rack
- 4U Rack
- 6U Rack

GLR PART NUMBERS

GLR PART NUMBERS	MODE	WATTS	COOLING	CABINET DIMENSIONS	HEAD DIMENSIONS W X D X H (mm)
GLR-10	CW	10 W	Air	3U Rack mount, 448 x 403 x 132	130 x 45 x250 (mm)
GLR-20	CW	20 W	Air	3U Rack mount, 448 x 403 x 132	130 x 45 x250 (mm)
GLR-30	CW	30 W	Air	4U Rack mount, 448 x 503 x 176	130 x 45 x250 (mm)
GLR-50	CW	50 W	Air	4U Rack mount, 448 x 503 x 176	130 x 45 x250 (mm)
GLPN-100-M	QCW	100 W	Air	OEM Module, 264 x 148 x 384	105 x 60 x 213 (mm)
GLPN-500-R	QCW	500 W	Water	6U Rack mount, 448 x 700 x 265	105 x 60 x 213 (mm)

Kilowatt class CW green lasers are also available, please contact your nearest sales office for further information.

GLP PART NUMBERS

GLP PART NUMBERS	MODE	WATTS	COOLING	CABINET DIMENSIONS	HEAD DIMENSIONS W X D X H (mm)
GLPN-M-10	Q-SWITCH	10 W	Air	OEM Module, 270 x 220 x 86	TBD
GLPN-10	Q-SWITCH	10 W	Air	3U Rack mount, 448 x 418 x 133	
GLPN-30	Q-SWITCH	30 W	Air	3U Rack mount, 448 x 418 x 133	
GLPN-50	Q-SWITCH	50 W	Air	3U Rack mount, 448 x 418 x 133	

PRODUCT SPOTLIGHT

IPG's New Product Releases & Standout Accessories

IPG continues to develop a wide range of products across a broad wavelength range, from continuous wave to ultra-short pulse duration. These new lasers open up new application areas to IPG, and allow the company to provide un-rivalled performance to new markets and industries such as medical, solar and semiconductor. Please contact us for more details on the full range of picosecond and femtosecond lasers.

NEW PRODUCT FEATURE: IPG's **GLPN-500-R** Green Quasi-CW Laser

NEW!

IPG Photonics introduces a new green fiber laser with ground-breaking maximum average power of 500 W in a perfectly single-mode output beam. IPG's GLPN-500-R takes advantage of the quasi-CW operation mode to allow for a high-efficiency super compact optical head that does not require any cooling. The optical head is connected to a water-cooled rack-mounted main laser console that houses highly-efficient and reliable fiber amplifier, pioneered by IPG. The result is a rugged industrial-grade high-power green fiber laser with unmatched performance and remarkable wall-plug efficiency. w for easy integration.

In addition, IPG's CW Ytterbium fiber laser modules can be ordered for single-mode operation or with step index fibers from 50 – 200 microns. This allows optimal performance for critical welding, cutting and drilling applications.

Applications

- Solar Cell Manufacturing
- Semiconductor Wafer Annealing
- Laser Shows
- Laser Projectors
- Welding & Cutting of Highly-Reflective Materials

Standard Features

- 532 nm Wavelength
- 500 Watt Output Power
- M^2 <1.2 Beam Quality
- 1% Power Stability
- Linear Polarization >100:1
- 2800 W Power Consumption
- Super Compact Head
- Industrial Performance

IPG'S COMPACT LASER SEAM STEPPERS:

A HIGH PRODUCTIVITY, HIGH-EFFICIENCY, CLASS I LASER SAFETY DEVICE; THE IDEAL REPLACEMENT FOR RESISTANCE SPOT WELDING.

IPG Photonics' Compact Laser Seam Steppers (LSS) are the ideal solution for freehand laser welding and as a replacement for resistance spot welding. Presenting two distinct units: the robot or gantry mounted LSS-2 and the hand-operated LSS-3, each stepper offers a unique laser clamping and welding tool that operates laser output powers up to 4000 Watts. With an adaptable clamping force of up to 3 kN and a fixed focal length of 250- 300 mm the LSS allows for a laser wobble seam weld up to 40 mm in length.

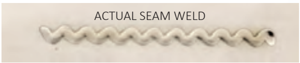
- Compact Design: Controller Dimensions (mm) 806 x 856 x 1508
- Up to 4 kW Laser Power with Laser Safety Class I
- Laser Welding with Simple Clamping Technology
- Reduced Processing Time due to Higher Joining Strength
- Compact Laser- and C-gun Control in a Single Housing
- Real Time Welding Quality Control & Data Record of each Welding Seam
- Programmable Clamping with Long-term Repeatability
- Repeatable Processing with Multi-layer Sheet Joining
- Higher Component Strength and Rigidity due to Joint Quality
- Smart Welding Option

LSS-2

The LSS-2 has high beam quality and ideal beam monitoring as well as an integrated protective cover allowing the Class 1 Laser classification. Powerful enough to easily weld even hot-formed materials, the LSS-2 cuts traditional weld speeds in half. Weighing in at only 45 kg, the design is compact and saves compressed air, allowing for operation below 70 dB.

LSS-3

IPG's LSS-3 Compact Laser Hand Seam Stepper represents a new generation of laser seam steppers. With a total weight of just 35 kg, the LSS 3 allows you to make welding seams by hand. The LSS-3 is unique in that it combines a clamping and laser welding tool which operates in power range up to 4 kW.



ACCESSORIES

Developed and Manufactured by IPG

PROVIDING TOTAL SOLUTIONS

IPG Photonics strives to provide the most comprehensive supply of fiber lasers, and with that, fiber laser solutions. To add to the functionality of the lasers and to enable IPG to provide one-stop service and support for the entire process, IPG manufactures its own line of processing heads, process fibers, collimators and chillers as well as tooling solutions developed from years of experience.

NEW!

NEW PRODUCT FEATURE: IPG'S HIGH POWER SCANNER

THREE-DIMENSIONAL SCANNER FOR HIGH SPEED CUTTING, MARKING OR WELDING

- Variable Spot Size Control:
  Tailor Power Density to Specific Applications
- Stationary, Synchronized & Mark-on-the-fly Robotic Applications
- Optional CCD Camera Attachment
- Maximum Processing Speed: 2 m/s
- 50 mm Clear Aperture
- 100 micron Fiber, Produces 450-750 µm Focused Spot
- Magnification: 4.5x - 7.5x
- Offset Drift: 10 micro radians/°C
- Gain Drift: 35 PPM/°C
- Operating Temperature: 0-50°C, Water-cooled optics
- Universal Input Voltage
- Industry Standard XY2-100 Control Interface
- Scanning Head Dimensions: 300 x 320 x 550 mm

DELIVERY OPTICS

D12.5 (Up to 3 kW use)

Compact Coupler, D12.5	P30-002126
Compact Shutter, D12.5	P30-002282
Compact 2-way Beam Switch, D12.5	P30-002125
Compact 4-way Beam Switch, D12.5	P30-002381

Optics listed are configured with IPG's standard HLC-8 (QBH compatible) connectors. LCA connectors (Automotive, QD style) and D50 part numbers are available upon request.

D25

Standard Coupler, D25	P30-001018
Standard Shutter, D25	P30-001352
Standard 2-way Beam Switch, D25	P30-001155
Standard 2-way Beam Splitter, 50:50, D25	P30-001400
Standard 3-way Beam Switch, D25	P30-001772
Standard 4-way Beam Switch, D25	P30-001156
Standard 4-way Beam Splitter, 50/50, 100/100, D25	P30-001397
Standard 4-way Beam Splitter, 50/50, 50/50, D25	P30-001662
Standard 6-way Beam Switch, D25	P30-001157

PROCESS FIBER PART NUMBERS (HLC-8 Connectors)

Custom lengths and diameters can be special ordered for process fibers.

LENGTH	100 µm	150 µm	200 µm	300 µm	400 µm	600 µm
10 meters	P45-002223	P45-002565	P45-002399	P45-002597	P45-003236	P45-003364
20 meters	P45-001914	P45-002756	P45-002171	P45-002510	P45-003163	P45-003164
30 meters	P45-002316	P45-002592	P45-002325	P45-002596	P45-003413	P45-003540

ADAPTABLE COLLIMATORS (HLC-8 Connectors)

FOCAL LENGTH	D25, Air-cooled	D25, Water-cooled
F50	P30-001459	P30-001354
F60	P30-001460	P30-001214
F70	P30-002387	P30-002384
F85	P30-001461	P30-001342

FOCAL LENGTH	D50, Air-cooled	D50, Water-cooled
F100	P30-001470	P30-001298
F120	P30-001471	P30-001277
F160	P30-001479	P30-001276
F180		P30-001433
F200		P30-001337

All accessories listed are configured with IPG's standard HLC-8 (QBH compatible) connectors.
LCA connectors are also available upon request depending on product. Please contact your salesperson for any additional configurations or options that may not be listed above.
Part numbers, configurations and availability subject to change.

PROCESSING HEADS

Cutting & Welding Heads for Fiber Lasers

Standard Features

IPG Photonics has revolutionized the cutting and welding industry, providing customers with reliable, compact and energy efficient fiber lasers. IPG now offers a range of optical heads to accompany its fiber lasers including the FLW-D30 and FLW-D50 welding heads and FLC-D30 cutting head.

The FLW-D30 and FLW-D50 welding heads have multiple features, including vertical or horizontal configuration, real time contamination monitoring functionality, camera options, fine focus adjustment and wide range of collimator and focus lens options, all packaged in a small, lightweight form, that weighs as little as 1.5 kg for the D30 and 2.5 kg for the D50. Available with a broad range of accessories including air-knife, gas assist/plume suppression, coaxial nozzle and angular mounting plate, IPG's welding heads can be configured the way you want.

The FLC-D30 cutting head is designed with an extremely low weight to keep the moving mass on cutting systems as low as possible. With constant height sensing and integrated electronics to monitor cover slide presence and contamination, the FLC-D30 is providing constant feedback. Supplied in straight or right angled configurations, with the broadest focus and collimator lens configurations available on the market, the FLC-D30 together with IPG's fiber lasers provides the perfect cutting solution.

FLC-D30 Vertical Configuration

FLC-D30

P30-002788 Base Part # FLC-D30 Cutting Head	A Vertical	1 50 mm	A 125 mm	1 HLC-8 (QBH type)
	B Horizontal	2 60 mm	B 200 mm	2 LCA (QD type)
		3 85 mm	C 250 mm	
		4 100 mm		

Example:

P30-002788-A4B1:

FLC-D30 Vertical Cutting Head with Manual Focus
100 mm Collimator
200 mm Focus
HLC-8 Fiber Receiver

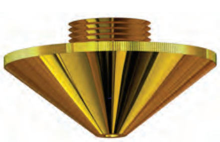
D30 Cutting Head Accessories

- Camera Arm Assembly: P30-002424
- Cover slides: P45-005047
- Cutting Nozzles:

Cutting Head Electronics

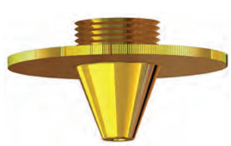
Motorized option with pierce detection
Monitoring for cover slide presence and contamination
Height sensor maintains constant distance to work piece
Integrated back reflection monitoring

Thick Nozzles



Diameters Available	IPG Part #
• 1.0 mm tip	P40-003805-002
• 1.2 mm tip	P40-003805-003
• 1.5 mm tip	P40-003805
• 2.0 mm tip	P40-007070
• 2.5 mm tip	P40-007071

Thin Nozzles



Diameters Available	IPG Part #
• 0.8 mm tip	P40-007141-001
• 1.0 mm tip	P40-007141-002
• 1.2 mm tip	P40-007141-003
• 1.5 mm tip	P40-007141-004
• 1.8 mm tip	P40-007141-005
• 2.0 mm tip	P40-007141-006
• 2.5 mm tip	P40-007141-007

FLW-D30 Horizontal Configuration

FLW-D50 Vertical Configuration

Camera Arm Assembly
P30-002424
C-mount extension tube to mount camera.
Precision image position adjustment.
Integrated iris. Image focus and lock.
Available for all processing heads.

FLW-D30

P30-002417
Base Part #
FLW-D30 Welding Head

Example:
P30-002417-S4E1:
FLW D30 Standalone Welding Head
100 mm Collimator
250 mm Focus
HLC-8 Fiber Receiver

Configuration		Collimator		Focus				Fiber Receiver	
R	Horizontal RHS	1	50 mm	A	100 mm	E	250 mm	1	HLC-8 (QBH type)
L	Horizontal LHS	2	60 mm	B	125 mm	F	300 mm	2	LCA (QD type)
V	Vertical	3	85 mm	C	150 mm	G	500 mm		
S	Standalone	4	100 mm	D	200 mm				

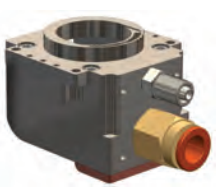
FLW-D50

P30-002418
Base Part #
FLW-D50 Welding Head

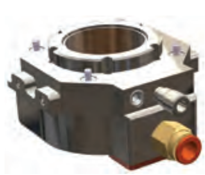
Example:
P30-002418-V4F1:
FLW D50 Vertical Welding Head
160 mm Collimator
500 mm Focus
HLC-8 Fiber Receiver

Configuration		Collimator		Focus				Fiber Receiver	
R	Horizontal RHS	1	100 mm	A	150 mm	G	600 mm	1	HLC-8 (QBH type)
V	Vertical	2	120 mm	B	200 mm	H	700 mm	2	LCA (QD type)
S	Standalone	3	140 mm	C	250 mm	I	800 mm	3	HLC-16 (FCH-16)
		4	160 mm	D	300 mm	J	900 mm		
		5	180 mm	E	400 mm	K	1000 mm		
		6	200 mm	F	500 mm				

Welding Head Accessories



Air-knife with Purge
P30-002163
Integrated purge module provides additional protection for cover slide
Gas assist can be attached to serve as plume suppression
FLW-D30 Version



Cross-Jet/ Air-knife
P30-007272
Integrated purge module provides additional protection for cover slide
Gas assist can be attached to serve as plume suppression
FLW-D50 Version

Coaxial Nozzle w/ Purge
P30-002650-XXX
Shield gas is delivered coaxially to the weld site
Telescoping option available.
Supresses weld plume
Consult IPG Sales for options
Available for FLW-D30.

Gas Assist
P30-002452
Can be attached to air knife or directly to head
Can be used to deliver off-axis shield gas to weld site
Suppresses weld plume
Multiple inputs
Available for FLW-D30 & FLW-D50

Welding Head Alarm Module
P30-007325
Monitors cover slide presence, contamination and temperature as well as mirror temperature
Available for FLW-D30 & FLW-D50

Part numbers, configurations, and availability subject to change. Cover slides and focus lenses also available.

COMPREHENSIVE SERVICES

What you can expect from IPG Photonics

PREMIUM WARRANTY & SUPPORT

IPG stands behind our commitment to our customers with the best warranty in the industry. All IPG lasers listed in this brochure are warranted against defects in materials and workmanship, under normal use, for minimum two years; three years for the YLS family of lasers with extended warranties available up to ten years.

Unlike conventional laser technologies, IPG fiber lasers require no preventive maintenance. As long as output optics and coolant are properly maintained by the customer, the laser will perform consistently without adjustment or intervention by the customer or IPG. This greatly reduces downtime and maintenance costs to the customer. We have a team of dedicated service professionals and technical support specialists worldwide to provide personal and effective customer support.

IPG PHOTONICS WORLD HEADQUARTERS, OXFORD, MA

Customer satisfaction is our goal at IPG. We strive to make the best lasers and amplifiers in the world and back it up with our commitment to service.

EXTENSIVE LASER SOLUTION DEVELOPMENT

IPG Photonics offers free applications development through any of our Materials Processing Centers worldwide. We offer prototyping and feasibility studies to our prospective customers to evaluate fiber lasers for their unique applications. Our knowledge of fiber laser applications can accelerate and improve your application development, from macro machining to micro machining and marking of various materials. Each of our applications labs offers our customers proof of concept, process development, recommendations, consultations, optical metrology, metallurgy, sample processing and an accompanying full results report.

APPLICATION FACILITY FEATURES:

5 Axis Robotics Welding, Cutting, Drilling

5 Axis CNC Welding, Cutting, Drilling

Tube Cutting Systems

CNC 2D Machines
- *Cutting, Welding Thick Plate*
- *High Speed Cutting*
- *Micromachining with High Accuracy*

Galvo Systems
- *Marking, Cutting, Welding*

APPLICATIONS CENTERS WORLDWIDE

COUNTRY	CITY	LAB FOCUS	PHONE	EMAIL
China	Beijing	Materials Processing	+86-10-6787-3377	application@ipgbeijing.com
China	Shanghai	Materials Processing	+86 21-5058-6566	application@ipgbeijing.com
China	Shenzhen	Materials Processing		application@ipgbeijing.com
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APPLICATIONS REQUEST FORM

Developing Your Laser Solution

PROCESS REQUEST
(PLEASE ATTACH TO SAMPLES)

IPG's Application Facilities are available to perform R&D for proof-of-concept through process development for all materials processing applications; end users and systems integration partners are welcome to visit and work at all facilities. If you would like IPG to process your application, please complete the fields below and send to your nearest IPG Applications Center. Please contact the site to schedule your work before submitting samples.

COMPANY NAME: ....

COMPANY ADDRESS: ....

CONTACT NAME: .... EMAIL: ....

TITLE: .... PHONE: ....

PART DESCRIPTION: ....

....

MATERIAL TYPE & DESIGNATION: ....

DESCRIBE ANY PRE- OR POST-PROCESS, MATERIAL TREATMENTS/ COATINGS, WHICH MAY INFLUENCE THE APPLICATION:

....

....

PROCESS: CUT ○ WELD ○ DRILL ○ OTHER ○ ....

PRINT ENCLOSED ○ MSDS ENCLOSED ○

PRODUCTION PROCESSING REQUIREMENTS: (answer all that apply)

PARTS PER HOUR	....	○ inch ○ mm		SURFACE FINISH	....	○ inch ○ µm
FEEDRATE	....	○ inch ○ mm		KERF WIDTH	....	○ inch ○ mm
HOLES/ MIN	....	○ inch ○ mm		HAZ	....	○ inch ○ mm
HOLE DIA.	....	○ inch ○ mm		RECAST	....	○ inch ○ mm
WELD DEPTH	....	○ inch ○ mm		DIMENSIONAL TOL	....	○ inch ○ mm

DESIRED CYCLE TIME: ....

LASER PREFERENCE: MULTI-MODE ○ SINGLE-MODE ○ PULSED ○

PRIMARY CONCERNS: (assign applicable concerns from 1 - 5, 1 being the most important)

SPEED	....	SURFACE FINISH	....	TAPER	....
KERF	....	HAZ	....	OTHER (specify)	....
DEPTH	....	POROSITY	....		

CURRENT PROCESS (and/or alternative process being considered) ....

....

....

DESCRIPTION OF CURRENT WORK HANDLER ....

....

PROJECT FUNDED? ○ YES ○ NO

PLEASE ATTACH ANY ADDITIONAL INFORMATION, SKETCHES, OR COMMENTS TO THIS SHEET AND ATTACH TO PROCESSING SAMPLES.

IPG PHOTONICS®

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Manufacturing, Development, Sales & Service

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IPGP NASDAQ LISTED

www.ipgphotonics.com

Fiber Laser Application Selection Guide

IPG PHOTONICS

Fiber Laser Application Selection Guide & Performance Overview

IPG's Ytterbium Fiber Lasers

IPG's QCW Fiber Laser

Overview

IPG Photonics' revolutionary fiber laser technology is available for a wide variety of materials processing applications. Our trouble-free, highly efficient laser sources have demonstrated their prowess over hundreds of thousands of hours of 24/7 operation at the multi-kilowatt power level; IPG's lasers have the most operational experience in this high technology field.

IPG offers ruggedized, continuous wave industrial fiber lasers over a wide power range: from 10 W-50 kW average power. Similarly, nanosecond pulsed lasers are available from 10-500 W average power. Many lasers are available in both rack-mount or OEM module formats so integrators can choose the most convenient and/or most cost-effective solution.

IPG also offers Mid-IR and Green wavelengths at lower power levels for either continuous wave or pulsed operation. IPG's Direct Diode Systems are offered in a full range of rack-mounted or module-based industrial systems.

Our highly experienced technology team will support laser system manufacturers to find the best solution for your needs.

IPG's Applications Facilities are staffed with highly experienced Laser Applications Professionals and can perform laser processing development from proof-of-concept through full process development for all materials processing applications; see back cover for locations and contact information.

The Power to Transform® Materials Processing with IPG's Fiber Lasers

Applications/ Lasers	YLR 1070 nm	YLM 1070 nm	YLR-QCW 1070 nm	YLP Series 1070 nm	YLP-RA 1070 nm	YLP-M 1070 nm	YLP-C 1070 nm	YLP-R 1070 nm	YLP-HP 1070 nm	YLP-G 532 nm	DLR 970 nm
Welding- Metals	X	X	X								
Welding- Plastics	X	X									X
Spot Welding (Flash-Lamp & DPSS YAG Laser Retrofit)	X	X	X								
Cutting- Metals	X	X	X		X			X		X	
Cutting- Polymers	X	X		X		X		X		X	
Cutting- Ceramics (Scribing)	X	X									
Cutting- Silicon	X	X		X					X	X	
Micromachining- Thin Film Removal/ Scribing				X		X		X	X	X	
Micromachining- High Speed Thin Film Removal				X		X		X	X	X	
Micromachining- Special Heat Affected Zone Requirements (HAZ)	X	X	X			X	X	X		X	
Micromachining- Reflective Surfaces	X	X		X				X		X	
Micromachining- Die Cutting				X				X	X	X	
Marking/ Identification:											
General Purpose- Metals		X		X		X	X			X	
General Purpose- Plastics				X		X		X		X	
General Purpose- Silicon				X						X	
General Purpose- Ceramics				X		X		X		X	
General Purpose- Some Organics				X				X		X	
High Quality Graphics/ Grayscale- Metals & Non-Metals				X			X				
Deep Engraving- Metals				X					X		
Special Heat Affect Zone Requirements (HAZ)	X	X	X			X		X		X	
Chemical Marking	X	X									X
Corrosion-Proof Marking (Dark)				X					X		
Decorative Color Marking	X	X		X							
Sintering	X	X	X								X
Brazing	X	X	X								X
Soldering	X	X									X
Heat Treating	X	X									X
Coating Removal (eg. Paint Stripping)				X					X		
Other:											
CO_2 Laser Retrofit	X	X	X	X		X			X		
Retrofit: DPSS YAG or Other	X	X	X	X		X	X			X	
Retrofit: DPSS 9XX nm Diode Laser System											X

The Power to Transform® with IPG's Low & Mid Power Infrared Lasers

Continuous Wave (CW) Fiber Lasers - Modulated to 50 kHz

YLR Series

IPG offers a full line of rack-mounted, CW fiber lasers at 1070 nm with power ranging from 20 W-1 kW. These lasers can be modulated to 50 kHz with pulse width down to 10 usec; other modulation options are also available. Lasers are available as single-mode with M^2=1.05, with options available for multi-mode feed fibers required for flat-top beam shaping. Air-cooled systems are available with up to 500 W average power and/or integrated collimators with up to 300 W average power. Other collimator and connector options are available as well as time-sharing and multi-porting optical options.

YLM Series

IPG's YLM Series, Ytterbium CW fiber laser modules, are designed for maintenance-free OEM applications with power options of 5, 10, 20 and 50 W. The YLM diode-pumped fiber laser delivers a diffraction limited (M^2<1.1) 1.07 micron laser beam directly to the work site via a metal-sheathed single mode fiber cable terminated by a collimator.

IPG's Green Laser Module

Long Pulse Quasi Continuous Wave (QCW) Fiber Lasers

YLR-QCW Series

This fiber laser is designed as an affordably priced, highly efficient alternative to flash lamp-pumped YAG lasers. A range of models from 150-900 W average power are available, in each case peak power is 10 times average power, maximum duty cycle is 10% at maximum peak power. High power models can have pulse energies as high as 60 J.

Pulsed Nanosecond Infrared Fiber Lasers

YLP Series

IPG also offers a range of general purpose, pulsed laser modules for marking, deep engraving and micro-machining. These laser modules, with M^2=1.5, offer various beam diameter options, integrated collimators, average power of 10-50 W, up to 1 mJ pulse energy and repetition rates of up to 200 kHz.

YLP-RA

IPG's YLP-RA is ideal for ablation processes requiring high peak power and excellent beam quality; a remote amplifier (RA) doubles the peak power to 20 kW while maintaining the pulse energy and mode quality (M^2=1.5).

YLP-M

IPG's YLP-M, with variable pulse length and higher frequency make this laser suitable for the small number of marking/micromachining processes that require finer process control than the YLP series offers.

PHOTONICS

The Power to Transform® with IPG's Low & Mid Power Infrared Lasers

Pulsed Nanosecond Infrared Fiber Lasers (continued from reverse)

YLP-C

IPG's YLP-C is designed specifically for gray scale, bit stream marking and applications that demand a more compact unit. These lasers have a fast turn-on, turn-off time with asynchronous triggering and are available in 1 mJ and 0.5 mJ versions with 100 nsec and 30 W.

YLP-R

IPG's YLP-R, a short pulse, high frequency laser (1-10 ns, >500 kHz) has a peak power of up to 40 kW and is well suited to very fine micro-machining applications.

YLP-HP Series

IPG's high power end of the YLP range with average power up to 500 W and pulse energy up to 50 mJ available at lower beam quality and longer pulse lengths. These rack-mounted lasers may be recommended for specific ablation processes; please contact IPG with your requirements.

Pulsed Nanosecond 532 nm Green Fiber Lasers

YLP-G

A 532 nm, green wavelength version of the YLP laser available in 5 and 10 W with each producing M^2=1.2. The 5 W version operates at a maximum of 300 kHz with 1.3 nsec pulse width and 0.014 mJ per pulse. The 10 W version operates at up to 600 kHz with the same fixed pulse width and pulse energy with no change in beam quality. This laser is best used for thin film removal.

DLR Series

Direct Diode Fiber Lasers

A full line of rack-mounted, direct diode, industrial grade CW lasers from 20 W to 1 kW at 970 nm typ. with other wavelengths available. These lasers can be modulated to 50 kHz with pulse width down to 10 µsec. Units are air-cooled to 500 W; other modulation and collimator options are also available.

Contact IPG's Applications Facilities to discuss complimentary sample processing.

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rev. 07/12

Exhibit B

Foreign Availability of 1 micron Lasers for Commercial Applications

Raycus FIBER LASER

锐 意 进 取　科 技 创 新

武汉锐科光纤激光器技术有限责任公司
Wuhan Raycus Fiber Laser Technologies Co., Ltd

地址：中国湖北武汉东湖开发区华中科技大学科技园创新基地10号楼　邮编：430223
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公司简介 Company Profile

锐意进取
科技创新

武汉锐科光纤激光器技术有限责任公司（以下简称“武汉锐科公司”），是中国第一家专门从事高功率光纤激光器及核心器件研发和规模化生产的企业，也是国内最大、全球有影响力的光纤激光器研发和生产基地。自2007年创建至今，已实现了10W-100W脉冲光纤激光器和5W-10000W连续光纤激光器两大系列产品的产业化，占国内30%的市场份额，并已出口亚洲、欧洲、美洲和中东地区。

武汉锐科公司具备年产脉冲光纤激光器6000台套，中高功率连续光纤激光器1000台套的生产能力。锐科光纤激光器产品覆盖调Q脉冲光纤激光器、窄脉宽光纤激光器、中高功率连续单模和多模光纤激光器、直接半导体激光器。

武汉锐科公司拥有国际一流的光纤激光器及其关键器件研发团队，拥有多项世界领先的专利技术。曾主持承担了国家科技支撑计划项目，国家重大科技专项和国家“863”计划等项目的研究，先后研制了国内第一台10W脉冲光纤激光器、第一台25W脉冲光纤激光器、第一台100W连续光纤激光器、第一台1000W连续光纤激光器和第一台4000W连续光纤激光器产品，并于2013年3月研制出国内首台10KW工业级光纤激光器，成为全球第二家研制出10KW级光纤激光器的企业。同时，武汉锐科公司也是中国光纤激光器行业标准(2012-2028T-JB)的牵头起草单位。

武汉锐科公司公司迄今已有四项成果通过省部级鉴定、两项成果获得湖北省科技进步一等奖。2010年通过ISO9001:2008质量体系认证，多个产品被列为国家重点新产品和湖北省名牌产品，并于2010年通过欧盟CE认证，2012年入选“国家火炬计划重点高新技术企业”，2013年被批准为湖北省光纤激光器工程研究中心和湖北省高功率激光装备工程技术研究中心以及博士后科研工作站。公司受到国家和业界的高度关注，习近平总书记等党和国家领导人曾分别听取锐科公司在高功率光纤激光器研发和产业化方面取得的成就汇报并给予高度肯定。

武汉锐科公司一贯秉承“立足国内，拓展国际”的市场战略，坚持“锐意进取，科技创新”的企业精神，以研发和生产高品质多样化适合各类工业加工用高功率光纤激光器产品为使命，我们的目标是持续引领中国高功率光纤激光器的发展，努力打造中国人自己的光纤激光器品牌，力争成为世界一流的光纤激光器制造商。

Wuhan Raycus Fiber Laser Technologies Co.,Ltd (Raycus) is the pioneering and leading developer and manufacturer of high power fiber laser and core components in China. Founded in 2007, Raycus has developed 10-100W Q-switched Pulsed fiber lasers, 5-10000W CW fiber lasers, short pulse MOPA structure fiber lasers, and direct diode lasers. To meet the requirement of fast growing market of industrial applications, Raycus keeps expanding its facility and product line and has built an annual production capacity of 6000 units of pulsed fiber laser and 1000 units of medium and high power CW fiber laser.

In 2010, Raycus was certified to CE and ISO9001:2008 for the quality of its products and management. As a leading supplier, Raycus products have been widely used by almost all laser integrators in China, and identified by the National New Products Program and have been accredited as name brand products. Raycus has established international markets in Europe, America , Japan , Korea and many other Asian territories.

Raycus is highly respected for its innovative research and development team, consisting of top scientists and engineers from international renowned companies. The company has bulit a very solid technology platform for the development of high power fiber lasers and core components. A number of its proprietary designs and innovation techniques have been patented in China and other countries. In 2011, Raycus was honored as the 'National Key Innovation Team of Oversea Chinese' by the Chinese State Council.

Raycus' mission is to develop and manufacture high quality industrial fiber lasers to meet and satisfy the requirements of worldwide customers. Raycus is working diligently to establish a national fiber laser manufacturing base in Optical Valley of China, Wuhan. The company's goal is to keep leading fiber laser development in China and become one of the leading fiber laser developers and manufacturers in the world.

Products Preview 产品预览

脉冲光纤激光器
Q-Switched Pulsed Fiber Lasers

启脉宽脉冲光纤激光器
Short Pulse Fiber Lasers

低功率连续单模光纤激光器系列产品
Low Power Single Mode CW Fiber Lasers

中功率单模连续光纤激光器系列
Medium Power Single Mode CW Fiber Lasers

直接半导体激光器
Direct Diode Laser System

高功率多模连续光纤激光器系列
High Power Multi Mode CW Fiber Lasers

低功率连续单模光纤激光器系列产品
Low Power Single Mode CW Fiber Lasers

产品说明 Introduction

锐科公司的低功率连续单模光纤激光器具有电光转换效率高、光束质量好、结构简单紧凑、免维护运行、性能稳定可靠等特点，广泛应用于激光指示、金属及非金属等材料的标记、精密加工、图文雕刻、及科学研究等领域。

Raycus' low power single mode CW fiber lasers feature compact design, high efficiency, near diffraction limited beam quality and maintenance free stable operation. They are widely used in laser pointing, metal and non-metal marking, graph engraving, scientific research and medical applications.

产品特点 Features

光束质量优异	Diffraction limited beam quality
体积小巧、重量轻	Light and compact design
集成化电气接口	Integrated electrical interface
安装方便	Easy installation
风冷设计	Forced air cooling

典型应用 Applications

标记	Marking
激光指示	Laser pointing
医疗	Medical
科研	Scientific research

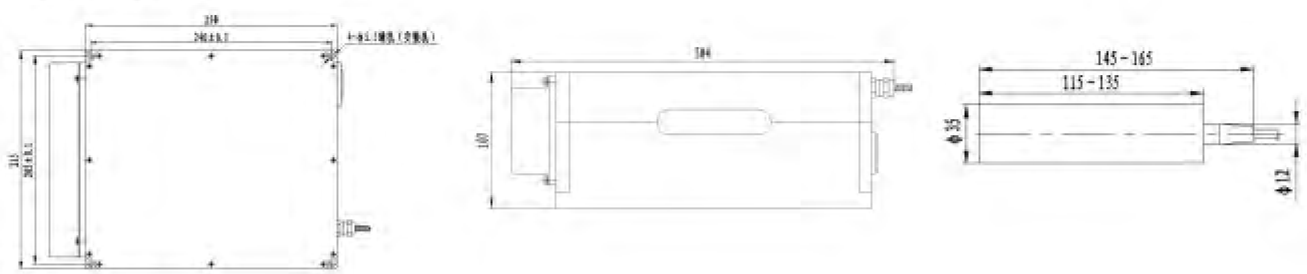
技术参数 Specifications

型号 Model	RFL-C5	RFL-C10	RFL-C20
光学特性 Optical Properties			
额定输出功率(W) Nominal Output Power	5	10	20
功率调节范围(%) Output Power Tunability	10-100		
中心波长(nm) Wavelength	1064		
运行模式 Operating Mode	连续/调制 CW/Modulated		
输出功率稳定度 Output Power Stability	<3%		
最大调制频率(KHz) Max. Modulation Frequency	50		
输出光斑直径(mm) Output Beam Diameter	4±1		
光束质量（M^2） Beam Quality	<1.05		
偏振态 Polarization State	随机 Random		
输出光纤长度(m) Delivery Cable Length	2		
电控特性 Electrical Characteristics			
输入电源 Power Supply	DC 24V		AC 220V 50/60Hz
最大功耗(W) Max. Power Consumption	35	55	100
其他特性 Other Characteristics			
尺寸(mm) Dimension	146×230×42		215×304×107
冷却方式 Cooling	风冷 Forced Air		
工作温度(℃) Operating Temperature Range	0-40		

以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size (mm)

20W CW Fiber Laser



脉冲光纤激光器
Q-Switched Pulsed Fiber Lasers

产品说明 Introduction

锐科公司10－100W调Q系列脉冲光纤激光器具有高峰值功率、高单脉冲能量、光斑直径大小可选的特点，能广泛应用于金属和非金属、具有高反特性的金、银、铜、铝等材料的打标、精密加工、图文雕刻等领域，尤其在激光打标应用领域，相比传统激光器成本更低廉，性能更稳定。该系列脉冲光纤激光器已有超过10000台在客户端使用，产品可靠性受到市场广泛认可，产品品质达到国际先进水平。

Raycus' 10-100W Q-switched pulsed fiber lasers feature high peak power, high pulse energy and optional output beam size. They are widely used in marking, precision drilling and engraving on non-metal and high reflection metals, such as gold, silver, aluminum and stainless steel etc.. Compared with traditional lasers, Raycus' Q-switched fiber lasers have lower cost and more stable performance in these applications. The key components of the lasers are developed and manufactured in house to ensure the lasers' reliability and uniformity. With more than 10000 lasers installed in the field, the reliability has been well proved.

产品特点 Features

高峰值功率	High peak power
高光束质量	Excellent beam quality
动态脉冲波形控制	Dynamic pulse shape control
高可靠性	Proved reliability
免维护运行	Maintenance free operation

典型应用 Applications

标记	Marking
深雕	Engraving
精密切割	Fine cutting
划线	Scribing
调阻	Trimming
ITO膜剥除	ITO thin film peeling

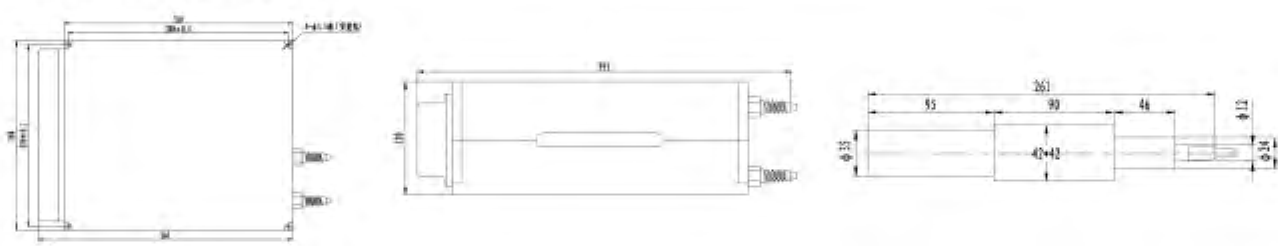
技术参数 Specifications

型号 Model	RFL-P10Q	RFL-P20Q	RFL-P30Q	RFL-P50Q	RFL-P100Q
光学特性 Optical Properties					
额定输出功率(W) Nominal Output Power	10	20	30	50	100
功率调节范围(%) Output Power Tunability	10-100				
中心波长(nm) Wavelength	1064				
重复频率范围(KHz) Repetition frequency range	20-80	20-80	30-80	50-100	50-100
输出功率稳定度 Output Power Stability	<3%				
输出光斑直径(mm) Output Beam Diameter	7±1				
光束质量（M²） Beam Quality(after beam expander)	<1.5		<1.8		<2.0
偏振态 Polarization State	随机 Random				
脉冲宽度（ns） Pulse Width	<100@20kHz	<130@20kHz			<200@50kHz
单脉冲能量(mJ) Single Pulse Energy	0.5@20kHz	1.0@20kHz	1.0@30kHz	1.0@50kHz	2.0@50kHz
输出光纤长度(m) Delivery Cable Length	2				
电控特性 Electrical Characteristics					
输入电源 Power Supply	DC 24V				AC 220V
最大功耗（W） Max. Power Consumption	120	200	250	300	500
其他特性 Other Characteristics					
尺寸(mm) Dimensions	260×391×120			396×360×123	484×490×185
冷却方式 Cooling	风冷 Forced Air				
工作温度(℃) Operating Temperature Range	0-40				

以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size（mm）

10-30W pulsed fiber lasers



窄脉宽脉冲光纤激光器
Short Pulse Fiber Lasers

产品说明 Introduction

锐科公司推出的全新窄脉宽脉冲光纤激光器，具有高峰值功率、脉宽可选、频率可调等特点，是精细打标、精密切割和微细加工等工业应用的理想选择。

Raycus NEW short pulsed fiber lasers feature high peak power, variable pulse width and tunable repetition frequency. They are ideal for precision marking, fine cutting and micromachining. The lasers with even higher power and shorter pulse width are under development.

产品特点 Features

产品特点	Features
高峰值功率	High peak power
脉宽可调可定制	Pulse width tunable
高光束质量	Excellent beam quality
风冷设计	Air cooling design

典型应用 Applications

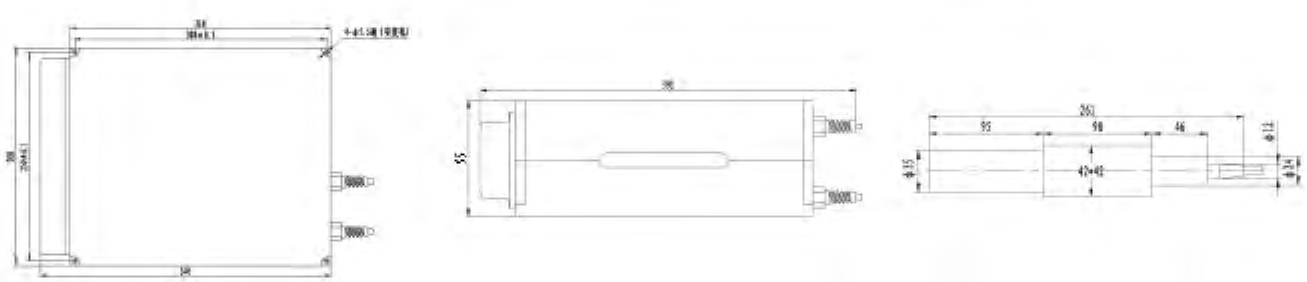
典型应用	Applications
精密标记	Precision marking
精密切割	Fine cutting
划线	Scribing
阳极铝刻蚀和毛化处理	Etching and texturing
调阻	Trimming

技术参数
Specifications

型号 Model	RFL-P10P	RFL-P20P
光学特性 Optical Properties		
额定输出功率(W) Nominal Output Power	10	20
功率调节范围(%) Output Power Tunability	10–100	
中心波长(nm) Wavelength	1064	
重复频率范围(KHz) Repetition Frequency Range	50 - 1000	
输出功率稳定度 Output Power Stability	<3%	
输出光斑直径(mm) Output Beam Diameter	7±1	
光束质量（M^2） Beam Quality(after beam expander)	<1.8	
偏振态 Polarization State	随机 Random	
脉冲宽度（ns） Pulse Width	1–30分档可调 1 - 30 variable	
单脉冲能量(mJ) Single Pulse Energy	0.1@100kHz	0.2@100kHz
输出光纤长度(m) Delivery Cable Length	2	
电控特性 Electrical Characteristics		
输入电源 Power Supply	DC 24V	
最大功耗(W) Max. Power Consumption	120	200
其他特性 Other Characteristics		
尺寸(mm) Dimensions	260×391×95	
冷却方式 Cooling	风冷 Forced Air	
工作温度(℃) Operating Temperature Range	0–40	

以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size（mm）



中功率单模连续光纤激光器系列
Medium Power Single Mode CW Fiber Lasers

产品说明 Introduction

锐科公司研制的中功率单模连续光纤激光器涵盖50W至500W，具有电光转换效率高、光束质量好、可靠性高、寿命长、免维护运行等优点，能广泛应用于不同材料的切割、焊接和精密制造等。在薄板金属材料切割应用中，该系列激光器切出的切缝窄且端面光滑，相对于同类型激光器优势明显。该系列激光器选用QCS或QBH光纤传输系统，具备多种控制模式和良好的兼容性。

Raycus provides a wide range of medium power (50 - 500W) single mode CW fiber lasers with excellent beam quality and up to 25% wall-plug efficiency. The lasers are designed to work in either CW mode or modulated mode with up to 50KHz repetition frequency. They are ideal for material processing applications such as cutting, welding and micromachining. By using many proprietary technologies, we can also offer 600-1000W single mode or 50-500W multimode fiber lasers for customer's specific applications.

产品特点 Features

- 电光转换效率高 / High efficiency
- 光束质量好 / Excellent beam quality
- 连续/调制模式 / CW or modulated mode
- QCS/QBH传输光纤可选 / QCS/QBH beam delivery cable
- 免维护 / Maintenance free

典型应用 Applications

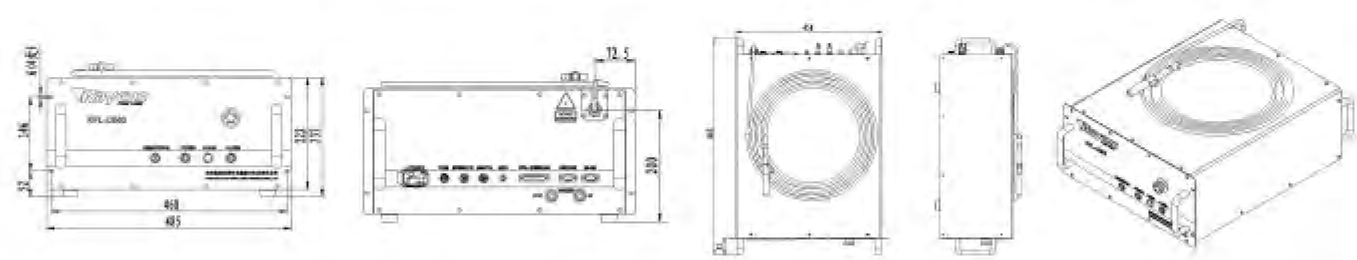
- 金属切割 / Metal cutting
- 金属焊接 / Metal welding
- 陶瓷切割与划片 / Ceramic scribing and cutting
- 快速成型 / Micromachining

技术参数 Specifications

型号 Model	RFL-C50	RFL-C100	RFL-C200	RFL-C300	RFL-C500
光学特性 Optical Properties					
额定输出功率(W) Nominal Output Power	50	100	200	300	500
功率调节范围(%) Output Power Tunability	10-100				
中心波长(nm) Wavelength	1080				
运行模式 Operating Mode	连续/调制 CW/Modulated				
输出功率稳定度 Output Power Stability	<3%				
最大调制频率(KHz) Max. Modulation Frequency	50				
光束质量（M^2） Beam Quality	<1.2				
偏振态 Polarization State	随机 Random				
输出光纤长度(m) Delivery Cable Length	10（选配15、20）(15/20 Optional)				
红光指示 Pilot Red Laser	有 Yes				
输出接头 Beam Delivery Optics	QCS（选配QBH）(QBH Optional)				
电控特性 Electrical Characteristics					
输入电源 Power Supply	AC 220V，单相，50/60Hz AC 220V，Single phase，50/60Hz				
控制模式 Control Mode	外部RS232/外部AD/超级终端 Ext. RS232/Ext. AD/Hyper terminal				
最大功耗（W） Max. Power Consumption	300	500	900	1200	2000
其他特性 Other Characteristics					
尺寸(mm) Dimensions	485×237×663(含把手) 485×237×663 (inc. handles)				
重量(kg) Weight	<50				
冷却方式 Cooling	风冷/水冷 Forced Air/Water Cooling			水冷 Water Cooling	
工作温度(℃) Operating Temperature	10-40				

以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size（mm）



直接半导体激光器
Direct Diode Laser System

产品说明 Introduction

锐科公司研制的RFL-DDL系列直接半导体激光器，具有电光转换效率高、调制频率宽、可靠性高、寿命长、运行免维护、结构紧凑等优点，可广泛应用于钎焊、塑料焊接、熔覆、表面热处理等领域。在熔覆应用中，锐科直接半导体激光器相对传统激光器的加工效率明显提高。此系列直接半导体激光器产品基于单管半导体芯片封装及大功率合束器技术，完全由锐科公司自主研制生产，电光转换效率接近50%，具有良好的兼容性，性价比高。

Raycus' RFL-DDL direct diode laser series feature high electrical-optical conversion efficiency, wide modulation frequency range, compact design, excellent long-term reliability and maintenance free stable operation. They can be used in brazing, plastic welding, cladding and surface heat treatment. RFL-DDL laser series have been proved with significant high efficiency in cladding applications compared with traditional lasers. Based on in-house single-emitter diode packaging and high power combiner technologies, Raycus can provide customized products for some specific requirements.

产品特点 Features

- 极高的电光转换效率 — Near 50% efficiency
- QBH输出光纤 — QBH beam delivery cable
- 免维护稳定运行 — Maintenance free stable operation
- 连续/调制模式 — CW/Modulated mode

典型应用 Applications

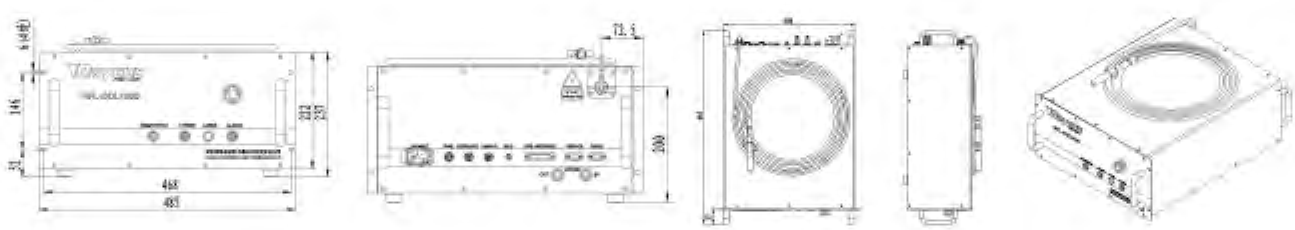
- 塑料焊接 — Plastic welding
- 熔覆 — Cladding
- 热处理 — Heat treatment
- 钎焊 — Brazing

技术参数 Specifications

型号 Model	RFL-DDL500	RFL-DDL1000
光学特性 Optical Properties		
额定输出功率(W) Nominal Output Power	500	1000
功率调节范围(%) Output Power Tunability	10-100	10-100
中心波长(nm) Wavelength	915	915
运行模式 Operating Mode	连续/调制 CW/Modulated	连续/调制 CW/Modulated
输出功率稳定度 Output Power Stability	<3%	<3%
最大调制频率(KHz) Max. Modulation Frequency	50	50
红光 Pilot Red Light	有 Yes	有 Yes
输出光纤 Beam Delivery Cable	QBH	QBH
光纤芯径（um） Fiber Core Diameter	400	500
光束发散角(rad) Output Beam Divergence	0.22	0.22
偏振态 Polarization State	随机 Random	随机 Random
输出光纤长度(m) Delivery Cable Length	10（可选15,20） (15/20 Optional)	
电控特性 Electrical Characteristics		
输入电源 Power Supply	AC 220V，50/60Hz, 单相 AC 220V，50/60Hz, Single phase	
控制模式 Control Mode	外部RS232/外部AD/超级终端 RS232/AD/Hyper Terminal	
最大功耗(W) Max. Power Consumption	1200	2000
其他特性 Other Characteristics		
尺寸(mm) Dimension	485×237×663(含把手) 485×237×663 (inc. handles)	
重量(kg) Weigh	<50	
冷却方式 Cooling	水冷 Water Cooling	
工作温度(℃) Operating Temperature Range	10-40	

以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size（mm）



高功率多模连续光纤激光器系列
High Power Multi Mode CW Fiber Lasers

产品说明 Introduction

锐科公司研制的高功率多模光纤激光器系列涵盖1KW至10KW，具有电光转换效率高、光束质量好、可靠性高、寿命长、免维护等优点，可广泛应用于金属材料的切割、焊接、表面处理和3D打印等领域。输出光学系统采用了加固铠装的输出光纤，输出接头为QBH，使客户配置更为方便。该系列产品的调制频率最高可达20KHz，能满足绝大多数应用场合的需求，并具备多种控制模式和，良好的兼容性。

Raycus' high power fiber lasers (1–10KW CW) are specially designed and manufactured for material processing such as fast cutting, welding, cladding, surface treatment and 3D printings. Based on modular design, the lasers offer very good reliability and easy maintenance. The lasers use standard QBH beam delivery optics, which make it very easy for industrial integration and robot applications.

产品特点 Features

- 模块化设计 — Modular design
- 高电光转换效率 — High efficiency
- QBH接头 — QBH beam delivery cable
- 输出光纤芯径可选，长度可定制 — Customized cable length，Fiber diameter optional
- 免维护 — Easy integration
- 易于集成 — Maintenance free

典型应用 Applications

- 切割 — Cutting
- 焊接 — Welding / Remote welding
- 熔覆 — Cladding
- 钻孔 — Drilling
- 3D打印 — 3D printing
- 表面处理 — Surface treatment

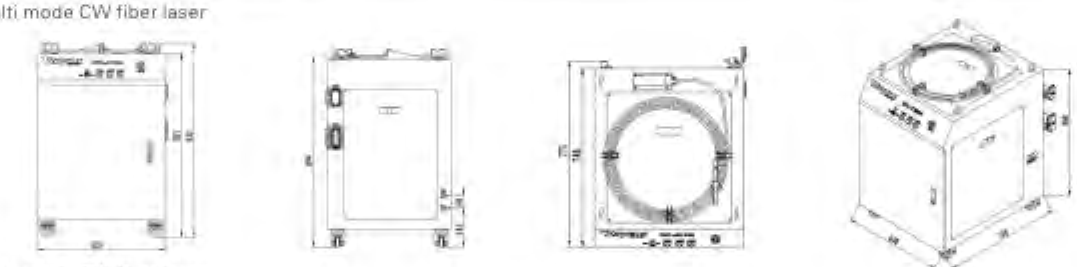
技术参数 Specifications

型号 Model	RFL-C1000	RFL-C2000	RFL-C4000	RFL-C10000
光学特性 Optical Properties				
额定输出功率(W) NominalOutput Power	1000	2000	4000	10000
中心波长(nm) NominalOutput Power	1080	1080	1080	1080
运行模式 Operating Mode	连续/调制 CW/Modulated			
最大调制频率(kHz) Max. Modulation Frequency	20	20	10	5
输出功率稳定度 Output Power Stability	<3%			
功率调节范围(%) Output Power Tunability	10–100			
偏振态 Polarization State	随机 Random			
红光 Pilot Red Laser	有 Yes			
输出接头 Beam Delivery Optics	QBH	QBH	QBH	定制
光纤直径（um） Fiber core diameter	50(可选100、200) (100/200 Optional)	100（可选200） (200 Optional)	100（可选200、300） (200/300 Optional)	200（可选300） (300 Optional)
输出光纤长度(m) Delivery Cable Length	15（可选20） (20 Optional)			
电控特性 Electrical Characteristics				
输入电源 Power Supply	AC380V，50/60Hz, 三相 AC 380V，Three phase，50/60Hz			
控制模式 Control Mode	外部RS232/外部AD/超级终端 Ext. RS232/Ext. AD/Hyper terminal			
其他特性 Other Characteristics				
尺寸(mm) Dimension	620×740×932	620×740×1433	1200×800×910	1800×950×1500
冷却方式 Cooling	水冷 Water Cooling			
工作温度(℃) Operating Temperature Range	10–40			

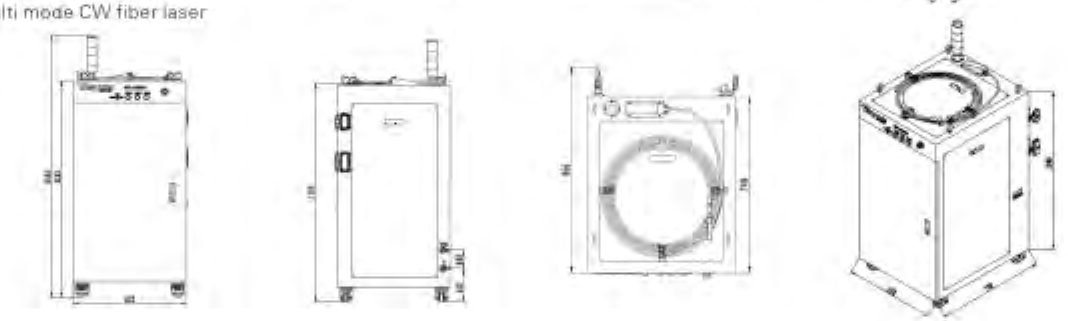
以上参数如有变动，恕不另行通知。
The above specifications are subject to change without notice.

产品尺寸图 Product Size（mm）

1KW multi mode CW fiber laser



2KW multi mode CW fiber laser



应用实例 Application Samples

切割 Cutting

打标 Marking

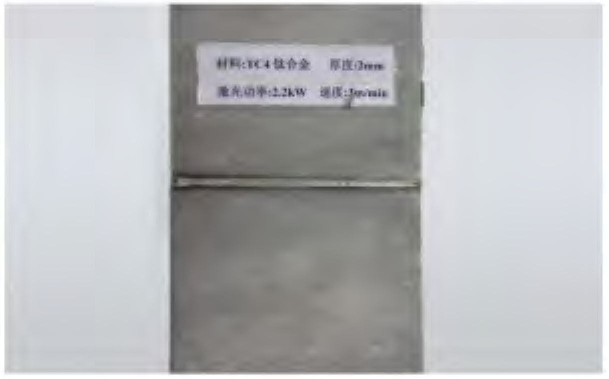
Application Samples 应用实例

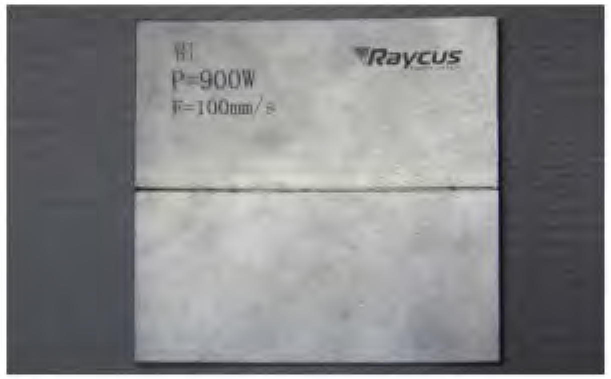
应用实例 Application Samples

深雕 Engraving

焊接 Welding

Application Samples 应用实例





MAX

激光中国芯

脉冲光纤激光器 | Pulse Fiber Laser

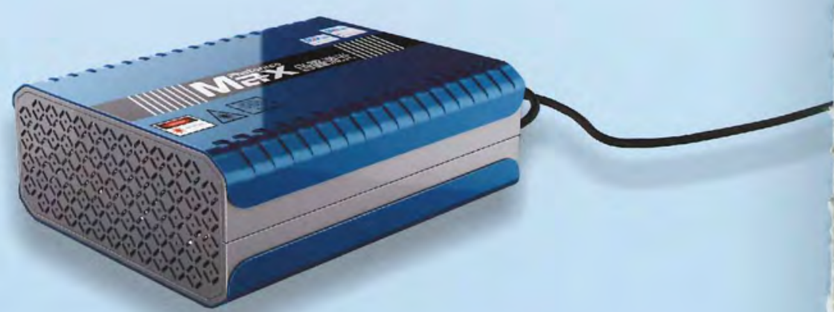
MaxPulse 系列

基本概况
BASIC PROFILE

MaxPulse系列声光调Q脉冲光纤激光器作为创鑫激光最具代表性产品之一，采用高可靠性、高度集成设计方案集众多优势于一身，迅速被广大客户所接收，市场占有率在同类产品中遥遥领先，用一个最好的词来形容它就是“安装即享受”。

此系列产品极大的满足用户需要，为客户实现最佳的经济效益。

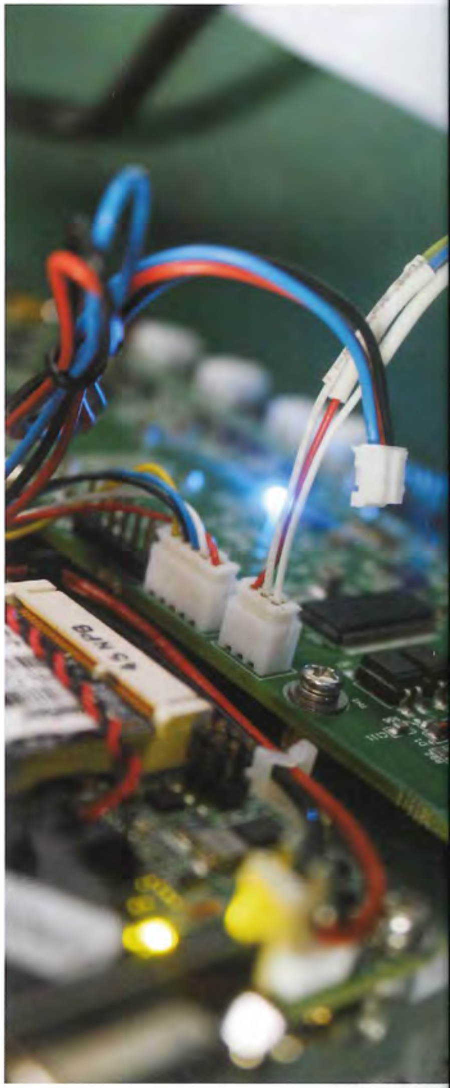
As the most representative products, the series of MaxPulse Q-Switch pulse fiber lasers use the design of high reliability and high integration, gather all of the advantages in one fancy package, and have been accepted by numerous customers, and occupied more market shares among all of the similar products, the most appropriate word for it, is “installing means enjoying”.



产品特点
PRODUCT FEATURE

- 开机时间短、光脉冲窄、峰值功率高、重复频率范围宽
- 在激光关断情况下无漏光
- 特殊材料加工不会出现阴影和虚断现象
- 具有抗高反特点，可在金，银，铝，铜等高反材料上进行加工
- 结构紧凑、体积小巧
- 高可靠性，超长使用寿命
- 通用的25针接口
- 立体感的外观设计

- Short turning on time, short pulse, high peak power, wide repetitive frequency range
- There is no leak when the lasers are switched off
- There is no shadow and Virtual circuit when process the special materials
- Anti-high-reflection function, could do machining on the materials of gold, silver, aluminium, copper etc
- Copact design
- High reliability, long lifetime
- Universal 25 pins interface
- 3D outward design



技术参数：
TECHNICAL PARAMETERS

Parameters	Unit	Data	Data	Data	Data	Data	Data
Type		MFP-5	MFP-10	MFP-20	MFP-30	MFP-50	MFP-100
Central emission wavelength	nm	1064±4	1064±4	1064±4	1064±4	1064±4	1064±4
Polarization		Random	Random	Random	Random	Random	Random
Nominal output power	w	5	10	20	30	50	100
Single pulse energy	mJ	0.5~0.6	0.5~0.6	0.8~1.0	0.8~1.0	0.8~1.0	0.8~1.0
Beam Quality	m^2	<1.4	<1.4	<1.8	<1.8	<2.0	<2.0
Beam Diameter	mm	6~8	6~8	6~9	6~9	6~9	6~9
Output power stability	%	<5	<5	<5	<5	<5	<5
Pulse width	ns	80~140	80~140	80~140	80~140	100~140	100~160
Output power tunability	%	5~100	5~100	5~100	5~100	5~100	5~100
Operation voltage	VDC	24	24	24	24	24	220VAC
Power consumption	W(20℃)	80	120	170	190	200	400
Fiber length	m	1.9/2.5/3	1.9/2.5/3	1.9/2.5/3	1.9/2.5/3	1.9/2.5/3	1.9/2.5/3
Cooling		Air cooling	Air cooling	Air cooling	Air cooling	Air cooling	Water cooling

因产品更新换代，参数会有所变化，请以实际为准 (All parameters is believed to be accurate and is subject to change without notice.)

应用 PRDOUCT APPLICATION

金属标记、部分非金属电镀材料、塑料橡胶、工程塑料、陶瓷等的打标、深雕、精细加工、特殊材料加工

Marking on metal, part of the non-metallic plating materials, plastic rubber, industrial-used plastics, ceramics and other marking; Deep carved; Fine processing; Special material processing

MaxMOPA 系列

基本概况
BASIC PROFILE

随着需要处理材料种类的日趋多样化，同时要求材料根据激光器施加能量做出不同的反应，市场需要更尖端和更具灵活性的加工工具出现，MaxMOPA系列光纤激光器应运而生。

MaxMOPA系列脉宽可调脉冲光纤激光器具有完美的激光特性和良好的脉冲形状控制能力，此系列激光器不受制于传统调Q技术的局限，允许用户改变脉冲持续时间，工作频率范围也更广泛。其脉冲频率和脉冲宽度相互独立控制，两个参数分别调节可实现恒定的峰值功率输出，使客户可以轻松定制脉冲参数以满足特定应用需求，将光纤激光器的标记应用推向更加广阔的市场。

As the processing materials become more and more various, and the materials should react differently according to the power from the lasers, so the market requires better machining tools with more flexibility, then the new series of MaxMOPA fiber lasers emerge as the times require.

MaxMOPA fiber lasers with adjustable pulse width have perfect performance and high quality pulse-shape control ability, the new series will not be limited by the traditional Q-Switch technology,then end-users could change the pulse continuous time, and this technology offers wider frequency range.The frequency range and pulse width could be controlled mutually and separately, the two parameters could be modulated independently to get a stable peak output power, so customers may customize pulse specifications easily to meet their specific application requirements and spread to much more broader market.

产品特点
PRODUCT FEATURE

- 平均功率/峰值功率 可达：20W/28KW,30W/33KW,50W/50KW
- 最低重频：25KHZ~50KHZ
- 最高重频达：500~1000KHZ
- 操作模式：脉冲
- 脉冲宽度可调，脉冲宽度：（5-20ns）~250ns
- 最大峰值功率涵盖整个操作频率范围
- 激光输出反射光隔离
- 高可靠性/重复性/稳定性设计
- 风冷系统设计
- Db25接口控制方式

- Average power / peak power up to: 20W/28KW, 30W/33KW, 50W/50KW
- Minimum frequency: 25KHZ ~ 50KHZ
- Maximum frequency: 500 ~ 1000KHZ
- Operation mode: pulse
- Adjustable pulse widthpulse width: (5-20ns) ~ 250ns
- Maximum peak power covers the whole frequency range
- Laser output reflection isolation
- Design of High reliability/repetitive/stability
- Design of Air cooling system
- Controlling method of Db25 interface

技术参数
TECHNICAL PARAMETERS

Parameters	Unit	Data	Data	Data	Data	Data	Data	Data	Data
Type		MFPT-5	MFPT-10	MFPT-20	MFPT-20*	MFPT-30	MFPT-50	MFPT-70	MFPT-100
Central emission wavelength	nm	1064±4	1064±4	1064±4	1064±4	1064±4	1064±4	1064±4	1064±4
Polarization		Random	Random	Random	Random	Random	Random	Random	Random
Nominal output power	w	5	10	20	20	30	50	70	100
Single pulse energy	mJ	0.5~0.6	0.5~0.6	0.5~0.6	0.67	0.8~1.0	0.8~1.0	0.8~1.0	0.8~1.0
Beam Quality	m^2	<1.4	<1.4	<1.8	<1.4	<1.8	<2.0	<2.0	<2.0
Beam Diameter	mm	6~9	6~9	6~9	6~9	6~9	6~9	6~9	6~9
Power reliability	%	<5	<5	<5	<5	<5	<5	<5	<5
Pulse width	ns	4~260	4~260	4~260	200	4~260	4~260	4~260	4~260
Output power tunability	%	5~100	5~100	5~100	5~100	5~100	5~100	5~100	5~100
Working voltage	VDC	24	24	24	24	24	24	24	220VAC
Power consupmtion	W(20°C)	80	100	120	120	140	160	180	250
Fiber length	m	1.9~3.5	1.9~3.5	1.9~3.5	1.9~3.5	1.9~3.5	1.9~3.5	1.9~3.5	1.9~3.5
Cooling		Air cooling	Air cooling	Air cooling	Air cooling	Air cooling	Air cooling	Air cooling	Watercooling

因产品更新换代，参数会有所变化，请以实际为准 (All parameters is believed to be accurate and is subject to change without notice.)

备注：MFPT-20*是专门针对市场上的打深要求比较高的一款产品，与同款MOPA产品相比具有以下优势：

1、峰值功率更高(>16KW) Higher peak power (>16KW)
2、单脉冲能量更大 Larger pulse energy
3、打深效果更佳 Better deep engraving performance

Remarks: MFPT-20 is specializing the higher requirements of deep engraving, it has the following advantages comparing with other MOPA products,

1、Higher peak power (>16KW)
2、Larger pulse energy
3、Better deep engraving performance

应用 PRDOUCT APPLICATION

氧化铝打黑、不锈钢打黑、陶瓷、塑胶标识、深雕、ITO膜加工、精密调阻、太阳能电池划线等

alumina black, stainless steel, ceramics, plastic signs, deep carving, ITO film processing, precision adjustable resistance, such as solar cell line marking

MAX

激光中国芯

中高功率连续光纤激光器

Mid and High Power CW Fiber Laser

激光中国芯
World to Benefit from China’s Fiber Laser

开创许多由于价格因素阻碍光纤激光应用的全新领域

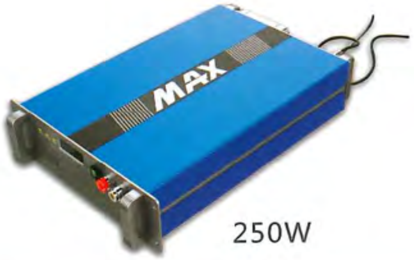
To drastically pioneer the new application field of fiber laser hindered by the price factors

加速推进全球市场光纤激光器替代传统激光器的战略步伐

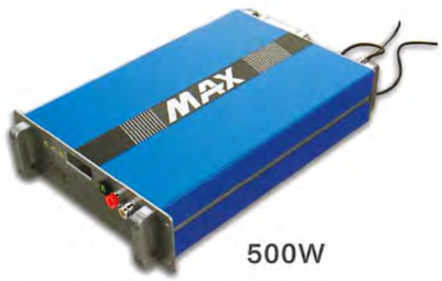
To strategically accelerate updating steps of fiber laser alternative to traditional laser in the global market

广泛应用于传统制造行业，推动国家装备制造业的产业升级

To be widely applied in the traditional manufacturing industry and greatly improve production efficiency



250W



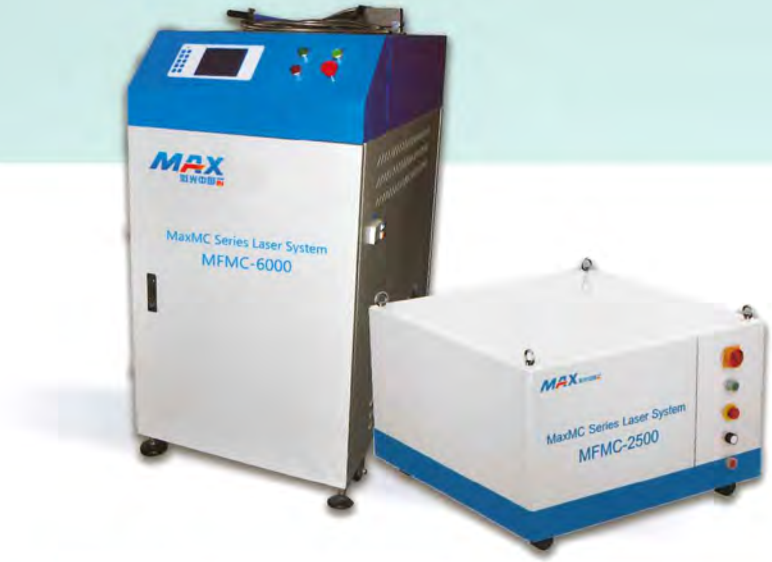
500W

800W

Parameters	Data	Data	Data	Data	Data	Data	Unit
Type	MFSC-250	MFSC-300	MFSC-500	MFSC-800	MFSC-1000	MFSC-1500	
Mode of operation	cw	cw	cw	cw	cw	cw	
Polarization	Random	Random	Random	Random	Random	Random	
Central emission wavelength	1080±4	1080±4	1080±4	1080±4	1080±4	1080±4	nm
Nominal output power	250	300	500	800	1000	1500	W
Output power tunability	10~100	10~100	10~100	10~100	10~100	5~100	%
Output power stability (t> 5h)	≤5	≤5	≤5	≤5	≤5	≤5	%
Output fiber length	5~20	5~20	5~20	5~20	5~20	5~20	m
Operation Voltage(DC)	220VAC	220VAC	220VAC	220VAC	220VAC	380VAC	V
Power consumption (at 20°C)	<1.5	<1.5	<2	<3	<4	<6	kW
Weight	50	50	55	60	65	80	kg
Cooling	Water cooling	Water cooling	Water cooling	Water cooling	Water cooling	Water cooling	
Size(L*W*H)	644*490*163	644*490*163	644*490*163	650*430*148	770*450*180	800*450*180	mm

因产品更新换代，参数会有所变化，请以实际为准 (All parameters is believed to be accurate and is subject to change without notice.)

PRODUCT INTRODUCTION
产品介绍



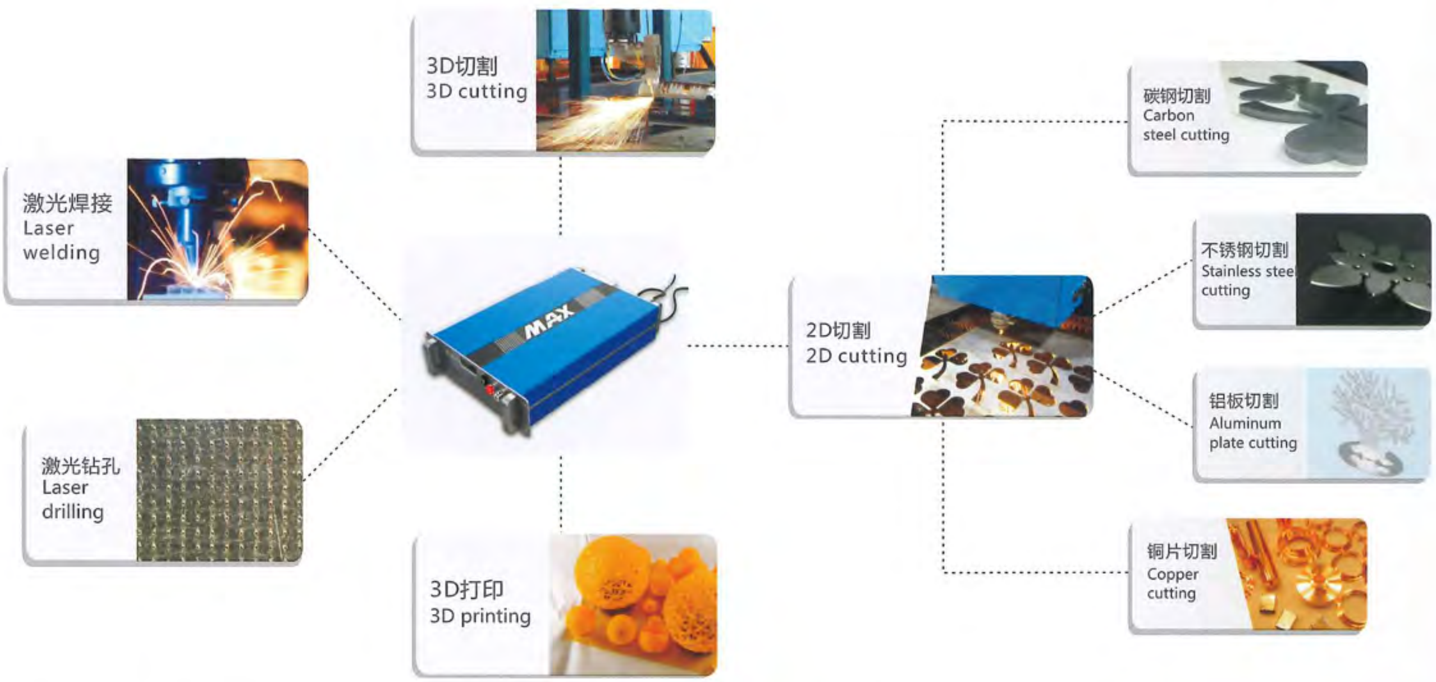
Parameters	Data	Data	Data	Data	Unit
Type	MFMC-2000	MFMC-2500	MFMC-4000	MFMC-6000	
Central emission wavelength	1080±10	1080±10	1080±10	1080±10	nm
Polarization	Random	Random	Random	Random	
Nominal output power	2000	2500	4000	6000	W
Feed Fiber Diameter	Available in 100,200 or 300 μm diameter				
Power stability(t>5h)	<3	<3	<3	<3	%
Output power tunability	5~100	5~100	5~100	5~100	%
Operation voltage	380	380	380	380	VAC
Power consumption	<8	<10	<16	<24	kW
Size(L *W*H)	856*806*1186	856*806*1186	1480*806*1482	2080*806*2082	mm
Fiber length	5~20	5~20	5~20	5~20	m
Cooling	water cooling	water cooling	water cooling	water cooling	
Operation temperature range	0~40	0~40	0~40	0~40	℃
Stockpile temperature range	-10~60	-10~60	-10~60	-10~60	℃

因产品更新换代，参数会有所变化，请以实际为准 (All parameters is believed to be accurate and is subject to change without notice.)

PRODUCT APPLICATION
应用

切割碳钢、硅钢、不锈钢、铝合金、钛合金、镀锌板、酸洗板、镀铝锌板、铜等多种金属材料。

To cut a variety of metal materials, including carbon steel, silicon steel, stainless steel, aluminum alloy, titanium alloy, galvanized sheet, pickling plate, aluminum zinc plate, copper.



光纤激光机器人三维切割系统是集高柔性、低成本于一体的智能化光机电产品。该系统利用机器人的空间运动优势和光纤激光器柔性传输的特点完美结合，堪称绝配！

The 3D cutting system of optical fiber laser robot is an integrated intelligent optical concentration with performance of high flexibility and low cost. The system is the perfect combination between the space motion of the robot and flexible transmission of fiber laser.

无处不在的光纤激光应用!
The ubiquity of fiber laser application

航空航天 Aeronautics and Astronautics

医疗行业 Healthcare industry

光伏行业 Photovoltaic industry

Kitchen utensils ar

汽车行业 Automotive industry

广告行业 Advertising industry

金属3D打印 Metal 3D printing

INDUSTRY APPLICATION
行业应用

Kitchen utensils and appliances industry厨具工业

Sheet metal industry 钣金行业

Petroleum industry 石油行业

Craft gift 工艺礼品

Lighting industry 灯饰行业

Mechanical equipment 机械设备

English | 中国

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- COMPANY

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Spectra-Physics Tel Aviv

HIGH QUALITY INDUSTRIAL FIBER LASERS

At Spectra-Physics' facility in Tel Aviv from our acquisition of V-Gen, we develop, manufactur and market high quality innovative laser systems for a wide range of industrial applications. T company's laser systems are the product of extensive experience and the cutting-edge know-how that our professional team has developed over many years. In the industrial field, the company develops and manufactures pulsed Ytterbium, Thulium, Erbium, Green and UV fibe lasers for such applications as micromachining, fine processing and marking. Our short pulse fiber lasers are also implemented in LIDAR and range-finding applications.

Products | Applications | Company | Privacy Policy | Contact Us

q-switched lasers

- FPDs/glass
- PCBs/ceramics
- semiconductors/LEDs
- solar cells
- additive manufacturing
- marking/engraving
- bio-instrumentation
- LIDAR

Q-SWITCHED PRODUCTS Q-SWITCHED APPLICATIONS

349 nm/355 nm | 532 nm | 1064 nm | 266 nm |

1064 nm Q-Switched Lasers Selection Guide

Product	Description	Power	Pulse Energy	Pulse Width
	VGEN-QS IR Q-switched fiber lasers	>100 W >75 W >50 W >30 W >20 W	>1500 µJ >1000 µJ >1000 µJ >500 µJ	125 ±25 ns
	HIPPO Versatile design for micromachining and scribing in a compact industrial package	>27 W >17 W	>560 µJ >560 µJ	<30 ns <15 ns
	Navigator Industry leading history/reliability for trimming and micromachining	>12 W >6.5 W >7 W >6 W >5 W	>1200 µJ >650 µJ >350 µJ >600 µJ >142 µJ	<80 ns <70 ns 70–110 ns 30–40 ns <8.5 ns
	Explorer DPSS IR lasers	>2.5 W	>30 µJ	<12 ns

q-switched lasers

- FPDs/glass
- PCBs/ceramics
- semiconductors/LEDs
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- LIDAR

Q-SWITCHED PRODUCTS Q-SWITCHED APPLICATIONS

Q-Switched Laser Applications

FPDs/Glass | PCBs/ Ceramics | Semiconductors/ LEDs | Solar Cells | Additive Manufacturing | Marking/ Engraving | Bio-Instrumentation | LIDAR

ITO laser patterning

TCO laser patterning

LDP/LDI, repairing LCD/PDP, and PDP/AM OLED processing

Inside glass laser marking and titling

Hole drilling, cutting, and machining

Black matrix patterning

fiber lasers

- marking/engraving
- FPDs/glass
- PCBs/ceramics
- semiconductors/LEDs
- solar cells
- LIDAR

Spectra-Physics, through its acquisition of V-Gen in Tel Aviv, manufactures high quality fiber lasers for precision micromachining, marking and LIDAR applications. Spectra-Physics' portfolio of fiber lasers covers IR to UV and pulsed to lower power CW.

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FIBER LASER PRODUCTS FIBER LASER APPLICATIONS

Pulsed IR | Pulsed Green | Pulsed UV | CW IR & Green

Product	Description	Power	Peak Power	Pulse Energy	Pulse Width
	VGEN-QS IR Q-switched fiber lasers	>100 W >75 W >50 W >30 W >20 W >10 W	>15 kW >15 kW >15 kW >10 kW >10 kW >5 kW	>1500 µJ >1500 µJ >1500 µJ >1000 µJ >1000 µJ >500 µJ	125 ±25 ns
	VGEN-ISP IR MOPA industrial short pulse fiber lasers	>50 W >30 W >30 W >20 W >20 W >20 W >20 W >10 W	>40 kW >40 kW >15 kW >20 kW >15 kW >15 kW >15 kW >10 kW	>1500 µJ >600 µJ >1000 µJ >500 µJ >450 µJ >600 µJ >1000 µJ >300 µJ	<1 to >300 ns <1 to >100 ns <5 to >200 ns <1 to >100 ns <1 to >300 ns <5 to >300 ns <5 to >200 ns <5 to >300 ns
	VGEN-SP Ytterbium short pulse fiber lasers for LIDAR (1064 nm)	>20 W >10 W	>25 or >40 kW >10, 15, 25 or >40 kW	>75 µJ or >100 µJ >45, 75, 100 or >200 µJ	<3 ns <3 to >50 ns
	VGEN-ESP Erbium short pulse fiber lasers for LIDAR (1550 nm)	>5 W >2 W		>15 kW	<3 to >50 ns

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fiber lasers

- marking/engraving
- FPDs/glass
- PCBs/ceramics
- semiconductors/LEDs
- solar cells
- LIDAR

Spectra-Physics, through its acquisition of V-Gen in Tel Aviv, manufactures high quality fiber lasers for precision micromachining, marking and LIDAR applications. Spectra-Physics' portfolio of fiber lasers covers IR to UV and pulsed to lower power CW.

FIBER LASER PRODUCTS FIBER LASER APPLICATIONS

Pulsed IR | Pulsed Green | Pulsed UV | CW IR & Green

Product	Description	Wavelength	Power
	VGEN-C CW IR Ytterbium fiber lasers (1060-1080 nm)	1060-1080 nm	>20 W >30 W >20 W >10 W
	VGEN-T CW mid-IR Thulium fiber lasers (1900-2100 nm)	1900-2100 nm	>10 W >20 W
	VGEN-G Pulsed and CW green fiber lasers (532 nm)	532 nm	>5 W

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cw / quasi-cw lasers

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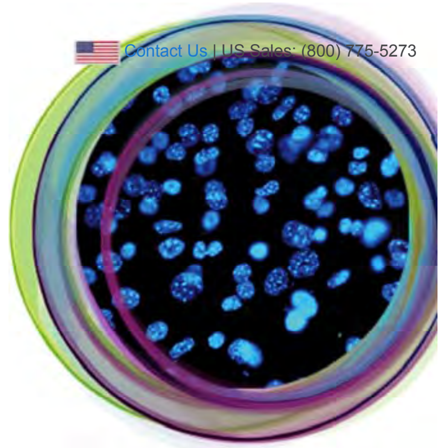


- bio-instrumentation
- bio-imaging
- metrology
- materials processing
- marking
- scientific

CW/QUASI-CW PRODUCTS CW/QUASI-CW APPLICATIONS

CW / Quasi-CW Lasers

Product	Description	Wavelength	Power
	Excelsior One Compact all-in-one CW lasers (OEM only)	375, 405, 445, 473, 488, 515, 532, 542, 553, 561, 594, 642, 785, and 1064 nm	10-500 mW
	Excelsior Compact CW lasers (scientific and OEM)	375, 405, 440, 473, 488, 505, 515, 532, 542, 561, 594, 642, 785, and 1064 nm	5-800 mW
	Millennia eV Highest power 532 nm pump lasers, up to 25 W	532 nm	5-25 W
	Millennia Edge 5 W single frequency 532 nm lasers	532 nm	5 W
	VGEN-G Pulsed and CW green fiber lasers (532 nm)	532 nm	>5 W
	Vanguard Mode-locked, Quasi-CW: reliable with proven longevity	355 nm 532 nm	350 mW-2.5 W 2 W
	VGEN-C CW IR Ytterbium fiber lasers (1060-1080 nm)	1060-1080 nm	>30 W >20 W >10 W
	VGEN-T CW mid-IR Thulium fiber lasers (1900-2100 nm)	1900-2100 nm	>20 W >10 W

Products | Applications | Company | Privacy Policy | Contact Us

TRUMPF

TruDisk lasers

TruDisk 4002.

The TruDisk disk laser combines the advantages of a solid-state laser with those of a diode. The diode as the pump source, provides the excitation energy and ensures high efficiency. The disk, as a solid-state laser, ensures high beam quality.

- High, power-independent beam quality
- Highest availability possible
- Powers from 1 to 16 kilowatts
- Compact design
- Simpler, quicker replacement of individual components
- Plug and play with all fiber diameters
- Beam quality from 2 to 8 mm*mrad

Category	Disk laser, diode-pumped solid-state laser
Products	TruDisk 1000 / 2000 / 2002 / 3001 / 3002 / 3006 / 4001 / 4002 / 4006 / 5001 / 5002 / 5006 / 6001 / 6002 / 6006 / 8001 / 8002 / 10002 / 10003 / 12002 / 12003 / 16002 / 16003
Application Fields	Cutting, welding, scanner welding, thick sheet metal welding, hybrid welding

Robust and reliable

The beam guidance, power supply, cooling system and control of the TruDisk laser are constructed in modules and accommodated in a compact housing. All the components are thought through in detail and adapted to one another. This results in highly reliable and robust laser systems in all operating conditions.

Process safety

The power of your laser can be regulated with great precision in real time. The required laser power at the workpiece remains constant all the time so that from the first second and over many years of production the results are always absolutely reproducible. The unique power range of 2 - 100% also enables a high application flexibility and the saving of relevant power data.

Low operating costs

Efficiencies of 30%, active power factor corrections, energy saving modes, ProfiEnergy and optimized cooling systems: All of these points have been considered and have been optimized to reduce your operating costs.

Overview **Technical Data** System Solutions Applications

	TruDisk 1000	TruDisk 2000	TruDisk 2002	TruDisk 3001
Wavelength	1030 nm	1030 nm	1030 nm	1030 nm
Laser power	1000 W	2000 W	2000 W	3000 W
Laser power (with upgrade)				
Beam quality	2 mm▪mrad	2 mm▪mrad	8 mm▪mrad	4 mm▪mrad
Min. diameter laser light cable	50 µm	50 µm	200 µm	100 µm
Power stability at nominal power	± 1 %	± 1 %	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C
Dimensions				
▪ Width	730 mm	730 mm	730 mm	1600 mm
▪ Height	1375 mm	1375 mm	1375 mm	1550 mm
▪ Depth	1120 mm	1120 mm	1120 mm	950 mm
	TruDisk 3002	**TruDisk 3006**	**TruDisk 4001**	**TruDisk 4002**
Wavelength	1030 nm	1030 nm	1030 nm	1030 nm
Laser power	3000 W	3000 W	4000 W	4000 W
Beam quality	8 mm▪mrad	25 mm▪mrad	4 mm▪mrad	8 mm▪mrad
Min. diameter laser light cable	200 µm	600 µm	100 µm	200 µm
Power stability at nominal power	± 1 %	± 1 %	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C
Dimensions				
▪ Width	1600 mm	1600 mm	1600 mm	1600 mm
▪ Height	1550 mm	1550 mm	1550 mm	1550 mm
▪ Depth	950 mm	950 mm	950 mm	950 mm
	TruDisk 4006	**TruDisk 5001**	**TruDisk 5002**	**TruDisk 5006**
Wavelength	1030 nm	1030 nm	1030 nm	1030 nm
Laser power	4000 W	5000 W	5000 W	5000 W
Beam quality	25 mm▪mrad	4 mm▪mrad	8 mm▪mrad	25 mm▪mrad
Min. diameter laser light cable	600 µm	100 µm	200 µm	600 µm
Power stability at nominal power	± 1 %	± 1 %	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C
Dimensions				
▪ Width	1600 mm	1600 mm	1600 mm	1600 mm

▪ Height ▪ Depth	1550 mm 950 mm	1550 mm 950 mm	1550 mm 950 mm	1550 mm 950 mm
	TruDisk 6001	**TruDisk 6002**	**TruDisk 6006**	**TruDisk 8002**
Wavelength	1030 nm	1030 nm	1030 nm	1030 nm
Laser power	6000 W	6000 W	6000 W	8000 W
Beam quality	4 mm▪mrad	8 mm▪mrad	25 mm▪mrad	8 mm▪mrad
Min. diameter laser light cable	100 µm	200 µm	600 µm	200 µm
Power stability at nominal power	± 1 %	± 1 %	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C
Dimensions ▪ Width ▪ Height ▪ Depth	 1600 mm 1550 mm 950 mm	 1600 mm 1550 mm 950 mm	 1600 mm 1550 mm 950 mm	 1990 mm 1550 mm 1200 mm
	TruDisk 10002	**TruDisk 10003**	**TruDisk 12002**	**TruDisk 12003**
Wavelength	1030 nm	1030 nm	1030 nm	1030 nm
Laser power	10000 W	10000 W	12000 W	12000 W
Laser power (with upgrade)	16000 W	16000 W	16000 W	16000 W
Beam quality	8 mm▪mrad	12 mm▪mrad	8 mm▪mrad	12 mm▪mrad
Min. diameter laser light cable	200 µm	300 µm	200 µm	300 µm
Power stability at nominal power	± 1 %	± 1 %	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C	5 °C - 20 °C
Dimensions ▪ Width ▪ Height ▪ Depth	 1990 mm 1550 mm 1200 mm	 1990 mm 1550 mm 1200 mm	 1990 mm 1550 mm 1200 mm	 1990 mm 1550 mm 1200 mm

	TruDisk 16002	**TruDisk 16003**
Wavelength	1030 nm	1030 nm
Laser power	16000 W	16000 W
Beam quality	8 mm▪mrad	12 mm▪mrad
Min. diameter laser light cable	200 µm	300 µm
Power stability at nominal power	± 1 %	± 1 %
Cooling water temperature range	5 °C - 20 °C	5 °C - 20 °C
Dimensions ▪ Width ▪ Height	 2800 mm 1550 mm	 2800 mm 1550 mm

▪ Depth	1400 mm	1400 mm

Subject to alterations. The specifications in our offer and our sales order confirmation are authoritative.

Laser power: At the workpiece regardless of the ambient temperature.

The above mentioned power stability applies for years

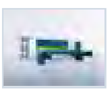
Higher laser power on request

Overview Technical Data **System Solutions** Applications

TRUMPF laser systems are perfectly coordinated with our lasers. A variety of options ensure that you always get a system perfectly tailored to your needs.

TruLaser Cell Series 7000
Prepared for every need.

TruLaser Robot Series 5000
The advantageous alternative for flexible 3D laser material processing.



TruLaser 1030 fiber

TruLaser 3030 fiber / 3040 fiber
Flexible standard machine

TruLaser 7025 fiber / 7040 fiber
Matchlessly productive

In addition, our lasers can be integrated into production lines.

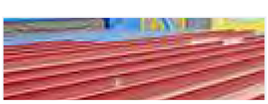
Overview Technical Data System Solutions **Applications**

Scanner laser welding

Scanner welding.

Whenever many welds must be performed in close proximity to one another, high-efficiency scanner laser welding is the right choice. Several hundred thousand scanner welds are carried out every day by TRUMPF disk lasers - in automotive production and suppliers - on doors, flaps, seats, and a variety of other components.

Hybrid laser welding



Using hybrid laser welding, thick sheets can be connected with large joining gaps. Sheet thicknesses of up to 20mm are already used in industry.


Hybrid laser welding

Due to its insensitivity to back reflections, the disk laser is the ideal laser tool for this application. Hybrid welding is used in automotive production, truck construction, shipbuilding, crane construction, the production of heavy machinery and construction machines, and in many other areas.

www.trumpf.com
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TRUMPF

TruMark Series 6000

TruMark Series 6000 - High marking precision

The TruMark Series 6000 consists of six different special lasers which have one thing in common: high power and outstanding beam quality combined to produce laser light of unique brilliance - available in any wavelength for surface processing.

- High marking precision
- Outstanding pulse-to-pulse power stability
- Easy to integrate
- Pluggable supply cable
- Internal software-controlled defocusing
- High temperature stability

Overview Technical Data System Solutions Options Applications

Category	Marking laser
Products	TruMark 6020, TruMark 6030, TruMark 6130, TruMark 6330, TruMark 6350
Application Fields	Laser marking, laser structuring, surface refinement

TruMark 6020

The TruMark 6020 emits infrared laser light (1064 nm) and is particularly well-suited for the processing of metal components, for instance for products in the automotive industry, the aircraft industry or in medical technology. The legal requirements for the traceability of products are high in these areas in particular. TruMark 6020 is a high-precision marking laser that guarantees process dependability for the reading of barcodes and data matrix codes.

TruMark 6030

The TruMark 6030 emits infrared laser light (1064 nm) and is particularly well-suited for the processing of metal components, for instance for products in the automotive industry, the aircraft industry or in medical technology. The legal requirements for the traceability of products are high in these areas in particular. TruMark 6030 is a high-precision marking laser that guarantees process dependability for the reading of barcodes and data matrix codes.

TruMark 6130

The TruMark 6130 works in the infrared range (1064 nm) and is characterized by high pulse power in high frequency ranges.

Therefore, it is particularly well-suited for plastic and semiconductor processing. The specific properties of the light of a vanadate laser, such as polarization, give the TruMark 6130 a characteristic profile which makes it the first choice in many applications.

TruMark 6330

The TruMark 6330 works at a wavelength of 355 nm in the UV range. This enables new capabilities in plastics processing. In contrast with infrared and green laser light, significantly better marking results can be obtained on many substrates, often at higher speeds and without the need for expensive laser-sensitive additives. Process stability and high mark quality are features of the TruMark 6330.

TruMark 6350

The TruMark 6350 works at a wavelength of 355 nm in the UV range. This allows you new possibilities in plastic processing. In contrast with infrared and green laser light, on many substrates significantly better marking results can be obtained, often at higher processing speeds, without the need for expensive laser-sensitive additives in the substrate. The TruMark 6350 gives you all the possibilities to implement customization and personalization in mass production. This is precisely where the TruMark 6350 can show its full advantages: process stability and high marking quality.

A new generation

The features trusted by the market under the name, VectorMark, are now combined with the latest technologies in the marking lasers of the TruMark Series 6000. At the same power levels, they are faster and, at the same frequency these marking lasers provide even more power than their predecessors.

Highly productive

For you this means higher productivity and more opportunities in material processing. TRUMPF is setting new standards in applied laser technology by combing technology and application expertise.

Overview **Technical Data** System Solutions Options Applications

	TruMark 6020	TruMark 6030	TruMark 6130	TruMark 6330
Laser medium	Nd:YAG	Nd:YAG	Nd:YVO4	Nd:YVO4
Wavelength	1064 nm	1064 nm	1064 nm	355 nm
Beam quality M²	1.2	< 1.2	1.2	1.2
Pulse repitition rate	1 kHz - 120 kHz	cw 1 kHz - 120 kHz	1 kHz - 120 kHz	1 kHz - 120 kHz
Focus diameter	~ 45 µm	at f=100; 26 µm	~ 40 µm	~ 25 µm
Marking field size (at f=160mm)				80 mm x 80 mm
Marking field size (at f=163mm)	120 mm x 120 mm	120 mm x 120 mm	120 mm x 120 mm	
		± 51,5 mm		
Scanner calibration accuracy	± 50 µm	± 50 µm	± 50 µm	± 50 µm
Connection and consumption				
▪ Electrical connection (voltage)	230; 115 V	230 : 115 V	230; 115 V	230; 115 V
▪ Electrical connection (frequency)	50; 60 Hz	50 : 60 Hz	50; 60 Hz	50; 60 Hz
▪ Electrical connection (current)	16 A	16 A	16 A	16 A
▪ Max. power consumption	1,7 kW	1,7 kW	1,7 kW	1,7 kW
▪ Average power consumption	1,4 kW	1,4 kW	1,4 kW	1,4 kW
Protection class	IP 54	IP 54	IP 54	IP 54
Dimensions and weight beam source				
▪ Width	200 mm	200 mm	200 mm	200 mm
▪ Height	301 mm	301 mm	301 mm	301 mm
▪ Depth	670 mm	670 mm	670 mm	670 mm
▪ Weight	32 kg	32 kg	32 kg	34 kg
Dimensions and weight supply unit				
▪ Width	445 mm	445 mm	445 mm	445 mm
▪ Height	645 mm	645 mm	645 mm	645 mm
▪ Depth	785 mm	785 mm	785 mm	785 mm
▪ Weight	104 kg	104 kg	104 kg	104 kg

	TruMark 6350
Laser medium	Nd:YVO4
Wavelength	355 nm
Beam quality M²	1.5
	1 kHz - 120 kHz

Pulse repetition frequency	
Focus diameter	~ at f = 160 mm: 35 µm
Marking field size (at f=160mm)	80 mm x 80 mm
Scanner calibration accuracy	± 50 µm
Connection and consumption	
▪ Electrical connection (voltage)	230; 115 V
▪ Electrical connection (frequency)	50; 60 Hz
▪ Electrical connection (current)	16 A
▪ Max. power consumption	1,7 kW
▪ Average power consumption	1,4 kW
Protection class	IP 54
Dimensions and weight processing unit	
▪ Width	200 mm
▪ Height	341 mm
▪ Depth	670 mm
▪ Weight	34 kg
Dimensions and weight supply unit	
▪ Width	445 mm
▪ Height	645 mm
▪ Depth	785 mm
▪ Weight	104 kg

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Overview Technical Data **System Solutions** Options Applications

TruMark Station 7000
Marking with capacity for big parts or a lot of tiny items

TruMark Station 5000
Flexible marking for every detail

Overview Technical Data System Solutions **Options** Applications

Options (Hardware)

Diverse focusing lenses

- Focusing lenses for different marking field sizes

Deflection 90°

- Beam output to the front

Dual Head System

- Asynchronous beam switch
- 100% laser power on either marking field
- Asynchronous mode: sequential marking of different or same content

Pilot laser

- Integrated laser diode beam for the simulation of the mark with visible light

Marking on the Fly (MOF)

- Mark moving parts (e.g. on a conveyor system)
- The velocity is continuously acquired and the and the marking is adjusted in real-time
- Mark endless work pieces

Options (Software)

Navigator

- Software based laser parameter assistant for choosing appropriate laser settings for a present marking application
- suitable for operators without special knowledge in laser treatment of material

Quick Flow

- Software tool module for easy programming of flow programs
- Object-oriented programming

Laser Power Calibration (LPC)

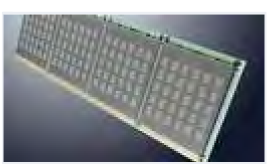
- The laser is calibrated on production site to a standardized value
- A power reserve compensates the natural power deterioration of the pump diodes
- The marking quality remains constant over the time

Screen segmentation

- For marking of large work piece surfaces and palletized work piece arrangements
- Segment size is freely definable within columns and lines

Overview Technical Data System Solutions Options **Applications**

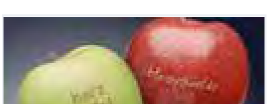
Laser marking



Workpiece: ICs

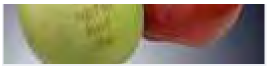
Industry: Semiconductor

Laser marking



Workpiece: Apple

Industry: Agriculture



Laser marking

Workpiece: Wafer

Industry: Semiconductor

Laser marking

Workpiece: Laser marked headrest Industry: Design

Laser marking

Workpiece: Laser marked exterior mirror glass

Industry: Automotive

Laser marking

Workpiece: Laser marked data matrix code on a solar cell

Industry: Solar

TRUMPF

TruMark

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TRUMPF

Home / Products / Laser Technology / Products / Solid-state lasers / Pulsed lasers / TruPulse

TruPulse lasers

TruPulse 124.

For any processing task, TruPulse lasers offer you the right parameters - tuned precisely to your production.

- 12 modules to choose from
- Custom adaptation of supply unit and beam guidance
- Ecellent reproducibility, thanks to high pulse-to-pulse stability
- Power Regulated Burst for high efficiency
- Convenient operation and control

Overview Technical Data System Solutions Applications

Category	Pulsed solid-state laser, lamp-pumped rod laser
Products	TruPulse 21 / 33 / 44 / 62 / 74 / 103 / 106 / 124 / 156 / 203 / 304 / 556
Application Fields	Spot welding, seam welding, scanner welding, cutting

The application focus of our TruPulse lasers is spot and seam welding. For components where heat input and therefore process time, must be low, "cold welding" with TruPulse lasers is particularly advantageous. Materials with high melting points can be welded just as well as materials with high heat conductivity. When cutting metal, TruPulse lasers produce fine contours.

Finely tuned

Several kilowatts of pulse power for a few milliseconds make welding and cutting possible where other methods fail. Power, energy or focusability - the TruPulse series covers the parameter range for welding and cutting. Maximum pulse powers of up to 10 kW, pulse durations from 0.2 ms to 50 ms, and maximum pulse energies of up to 120 J make them useful for many purposes - both in manual and automated operation.

Modular

Beam generation, beam guidance, power supply, cooling and control are all modular in design. Everything is thought out to the last detail. A laser can serve up to six processing stations. The laser beam is divided or a time offset is used to guide it to the workpiece. TruPulse lasers up to 150 watts can be air or water cooled.

Best results

The clocked power supply is highly dynamic. An extremely short pulse rise time combined with the fast real-time power control results in high pulse-to-pulse stability (deviation < ±0.3% at 10 ms pulse duration). Thus your processing results are consistent at all times.

The pulse frequency of a laser is normally limited by the pulse energy and average power. With the Power Regulated Burst, the average power can temporarily be exceeded by a factor of several times, reducing the welding time in one processing cycle to a minimum. Long Pulse Welding also opens up new possibilities. With a single laser pulse, you can produce a welding seam by quickly moving the workpiece or the laser beam.

Helpful

An optional application wizard database assists in determining the best welding parameters for your application. With Quality Data Store, you can record, evaluate and track relevant laser parameters to meet strict quality requirements.

Overview **Technical Data** System Solutions Applications

	TruPulse 21	**TruPulse 33**	**TruPulse 44**	**TruPulse 62**
Wavelength	1064 nm	1064 nm	1064 nm	1064 nm
Average power	20 W	30 W	40 W	60 | 65 W
Max. pulse power	1.5 kW	3 kW	3 kW	3 | 5 kW
Max. pulse energy	15 J	30 J	30 J	20 | 50 J
Pulse duration	0.2 ms - 50 ms	0.2 ms - 50 ms	0.2 ms - 50 ms	0.2 ms - 50 ms
Beam quality	4 mm▪mrad	12 mm▪mrad	16 mm▪mrad	8 mm▪mrad
Min. diameter laser light cable	100 µm	300 µm	400 µm	200 µm
Cooling water temperature range	6 °C - 30 °C	6 °C - 30 °C	6 °C - 30 °C	6 °C - 28 °C
	TruPulse 74	**TruPulse 103**	**TruPulse 106**	**TruPulse 124**
Wavelength	1064 nm	1064 nm	1064 nm	1064 nm
Average power	70 | 70 W	95 | 95 | 90 W	110 W	140 | 125 | 110 W
Max. pulse power	4 | 6 kW	5 | 6 | 8 kW	4 kW	6 | 6 | 9 kW
Max. pulse energy	30 | 60 J	30 | 60 | 90 J	30 J	30 | 70 | 90 J
Pulse duration	0.3 ms - 50 ms	0.3 ms - 50 ms	0.3 ms - 50 ms	0.3 ms - 50 ms
Beam quality	16 mm▪mrad	12 mm▪mrad	25 mm▪mrad	16 mm▪mrad
Min. diameter laser light cable	400 µm	300 µm	600 µm	400 µm
Cooling water temperature range	6 °C - 28 °C	6 °C - 28 °C	6 °C - 28 °C	6 °C - 28 °C
	TruPulse 156	**TruPulse 203**	**TruPulse 304**	**TruPulse 556**
Wavelength	1064 nm	1064 nm	1064 nm	1064 nm

Average power	150 | 160 | 140 W	200 W	300 W	530 W
Max. pulse power	6 | 6 | 10 kW	6 | 8 kW	10 | 10 kW	10 | 10 kW
Max. pulse energy	30 | 80 | 120 J	55 | 90 J	60 | 90 J	60 | 100 J
Pulse duration	0.3 ms - 50 ms	0.3 ms - 50 ms	0.3 ms - 50 ms	0.3 ms - 50 ms
Beam quality	25 mm▪mrad	12 mm▪mrad	16 mm▪mrad	25 mm▪mrad
Min. diameter laser light cable	600 µm	300 µm	400 µm	600 µm
Cooling water temperature range	6 °C - 28 °C	6 °C - 28 °C	6 °C - 28 °C	6 °C - 28 °C

Subject to alterations. The specifications in our offer and our sales order confirmation are authoritative.

Overview Technical Data **System Solutions** Applications

TRUMPF laser systems are perfectly tuned to our lasers. A wide variety of options ensure that you always get a system perfectly tailored to your needs.

In addition, our lasers can be integrated into production lines.

Overview Technical Data System Solutions **Applications**

Laser welding


Mobile phone housing.

Lasers are used in several places in the production of mobile phones. TruPulse lasers are used to trim the deep-drawn components on a 3D laser processing system. Multipart mobile phone housings are welded by TruPulse lasers, with spot welds and seams of precisely-defined depths.

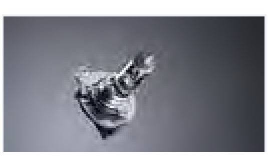
Laser welding


Plug connections.

Today's electronics production would not exist without lasers.

TruPulse lasers weld plug contacts in automatic punch presses at several hundred strokes per minute. This is made possible by guiding the beam using a fiber-optic laser cable and compact focusing optics.

Laser welding



The lighting properties of halogen lamps for automotive headlights are precisely measured during production. The lamps and sockets are adjusted individually and fastened at multiple points without distortion, thanks to the multiple beam splitting feature of TruPulse lasers.

Halogen lamp.

Laser welding

Pacemaker.

Welding gas-tight titanium pacemaker housings is no problem for TruPulse lasers. The sensitive electronics are never heated above 122° F.. There is no weld spatter in the interior because the weld depth can be precisely adjusted and the heat of the overlapping weld point is distributed over the housing.

Laser welding.

When material is missing due to wear, damage or even design changes, deposition welding with TruPulse lasers can help.

- In tool and mold production for the repair of injection molding tools.
- In mechanical engineering for the repair of bearing seats.
- In turbine construction for the repair of turbine blades.

TRUMPF
Sales Laser Technology
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Email: oem.info@us.trumpf.com

ROFIN FL Series

High Brightness Fiber Lasers for Every Application

All fiber lasers of the ROFIN FL Series are extremely efficient. With their modular and robust design the lasers have been set-up for optimum reliability. They offer excellent single-mode or multi-mode beam qualities, which can be precisely adapted to the processing task and therefore represent a universal tool for industrial production. They are suitable for cutting, welding, and surface treatment, as well as for a wide variety of scanner-based applications. The emitted wavelength of 1 µm achieves high absorption in many materials and is especially suitable for processing highly reflective materials.

The lasers are equipped with the ROFIN Control Unit (RCU), which offers, besides numerous monitoring tasks, e-service capability as well as simple implementation of scanner-based applications.

The “compact” version with a spliced fiber and a small cabinet is ideally suited for easy integration into existing systems and the “standard” version offers a separated enclosure for beam management. Up to four fibers can be used with time or energy sharing including two channel interlocks per output and a multi-station fieldbus interface. By using different diameters of the process fiber, the beam quality can be ideally adapted to the specific application task.

All fiber lasers of the FL Series are characterized by maximum efficiency and service friendly, modular pumping units, helping to reduce operating and maintenance costs.

Technical Data

Standard Versions:
FL x50, FL x75, FL 010, FL 015, FL 020, FL 030, FL 040, FL 060, FL 080

Excitation:	Laser diodes
Output power:	500 W; 750 W; 1,000 W; 2,000 W; 3,000 W; 4,000 W; 6,000 W; 8,000 W
Beam parameter (using a 100 µm fiber):	3-4 mm x mrad
Available fiber optics:	50 - 1,000 µm for 500 W - 2,000 W 100 - 1,000 µm for 3,000 W and higher

Compact Versions:
FL x50 C, FL x75 C, FL 010 C, FL 015 C, FL020 C, FL 030 C, FL 040 C, FL 060 C, FL 080 C

Excitation:	Laser diodes
Output power:	500 W; 750 W; 1,000 W; 2,000 W; 3,000 W; 4,000 W; 6,000 W; 8,000 W
Beam parameter (using a 20 µm fiber):	≤ 0,4 mm x mrad
Beam parameter (using 50 µm fiber):	≤ 2,5 mm x mrad
Beam parameter (using 100 µm fiber):	3-4 mm x mrad
Available fiber optics:	20 µm for up to 2,000 W 50 and 100 µm for 500 W - 3,000 W

Worldwide Locations

Internat. Websites

Trade Fair:

01.07. - 03.07.2015
LASER KOREA 2015
Korea, Seoul

14.07. - 15.07.2015
SEMICON WEST USA
USA, San Francisco

Trade Fair calendar

100 µm for 4,000 - 6,000 W

Available as Single-Mode Versions:
FL x50 C, FL x75 C, FL 010 C, FL 015 C

All Compact Versions are available as Multi-Mode Lasers

Typical Applications

- 2D and 3D cutting of mild and stainless steel
- Laser cutting of nonferrous metal
- Spot and seam welding
- Scanner welding in particular in the automotive industry
- Laser deposit welding

Download

Brochure: ROFIN FL Series (English) PDF (1.1 MB)

ROFIN DF 060 HP

Efficient, Powerful and Reliable

ROFIN's fiber-coupled diode laser with 6 kW output power is an ideal tool for brazing, cladding and surface treatment applications due to its smooth an homogenous beam profile and the high efficiency. The wavelength close to 1 µm achieves high absorption in many materials and ensures best results.

Converting electrical power directly into laser radiation – that's the by far most efficient way. Inside a ROFIN diode laser, multiple diode laser modules – each providing an optical output power of 1kW – are combined together and coupled into a multi-mode single core fiber. Each module is monitored individually and can be replaced on site if necessary.

The modular design allows flexible power scaling and ensures high availability as well as ease of maintenance. In addition, standardized customer interface and a remote access for diagnostics provide highest user-friendliness. The robust system comes with an integrated cooling unit enabling the use of process water which is available in the most industrial areas.

Technical Data

Output Power	6 000 W
Wavelength	900 - 1 000 nm
Beam parameter (using a 1 000 µm fiber)	110 mm x mrad
Available fiber optics	1 000 µm

Typical Applications

- Laser Brazing
- Laser Hardening
- Laser Cladding

Download

Brochure: ROFIN DF 060 HP (English) PDF

PowerLine F Series

Fiber lasers with different output powers for micro and marking applications

The PowerLine F series comprises innovative fiber lasers ith different power ranges. All Systems deliver 1 mJ pulse energy with a fast turn-on time and high Peak power over a wide range of Repetition rates. The emitted average laser power can be set using the fibe amplifier.

The PowerLine F 20 Varia's adjustable pulse length provides perfect results even with challenging applications (e.g. corrosion-free marking). Best marking results can be achieved with the PowerLine F 20 Varia in every case in which high material removal is required at high speed as well as when it comes to fine material removal.

The PowerLine F 50 and F 100 are operated in pulse modes at frequencies up to 200 kHz. As a result the PowerLine F 50 and F 100 are perfectly suitable for high-speed marking, scribing, edge isolation, structuring and cutting applications.

Specific Versions of the product line are available e.g. for semicon applications (PowerLine F IC) and security documents (PowerLine F PC).

Typical Applications

- marking
- engraving
- etching
- trimming
- scribing
- edge Isolation
- structuring
- cutting

Features at a glance

- different power ranges for various applications
- completely air-cooled
- low operating costs
- single and double galvo
- compact laser head

Power range:	20 W, 30 W, 50 W, 100 W
Laser type:	diode-pumped fiber Yb
Wavelength, (typ.):	1064 nm
Marking field:	120 x 120 mm
Power consumption:	330 VA, 390 VA, 470 VA, approx. 570 VA, approx. 350 VA (PowerLine F 20 Varia)

Typical Applications

- Laser marking of metals and plastics
- Day & Night laser marking

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Download

PowerLine F English.pdf PDF (0.9 MB)

PowerLine E Series

End-pumped Solid-State Lasers with a Wide Range of Applications

Laser markers for a wide range of applications which are particularly easy to integrate and to maintain. The system comes with Visual LaserMarker (VLM), an application software which allows the layout, generation and transfer of the required marking data to be sent straight from the PC to the laser marker. Depending on application requirements the lasers of the PowerLine E product line are available as air-cooled, water-air-cooled, in different wavelengths (1064 nm, 532 nm, 355 nm) and various power ranges.
Specific versions of the product line are available e.g. for semicon applications (PowerLine E IC), security documents (PowerLine E PC) and for the solar industry (PowerLine E PV).

Features at a glance

- different power ranges
- Several wavelengths
- single and double galvo configuration
- easy integration through compact design

Laser type:	diode end-pumped Nd: YVO_4
Output power class up to:	10 W - 40 W
Wavelength:	1064 nm, 532 nm, 355 nm
Pulse frequency:	1 – 200 kHz, and CW
Marking field:	120 x 120 (other dimensions on request)
Power consumption:	0.5 kW - 1.88 kW

Typical Applications

- Lasermarking of metals and plastics
- day & night laser marking

Download

Laser Marking: Superior solutions for a wide range of applications PDF (7.2 MB)

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USA, San Francisco

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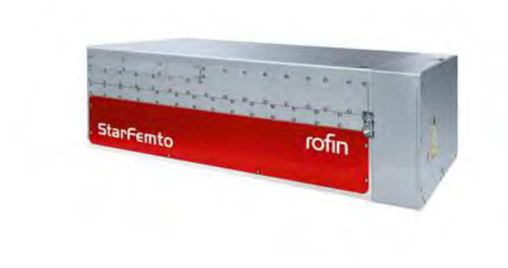
StarFemto

The Industrial Solution



Customer Benefits

- ROFIN Hybrid MOPA architechture
- Robust design
- ROFIN global on-site support
- Easy system integration and maintenance
- Made in Germany
- 700 fs pulse width, 20 W laser power
- Programmable Burst Mode (patented)
- Repetition rate from single pulse to 2 MHz
- Fast parameter change
- Integration packages for various applications

Technical Specifications

StarFemto		*E*	*M*	*L*
Wavelength	nm	1030		
Max. Output power	W	20		
Max. Pulse energy	µJ	20	100	160
Pulse width (FWHM)	fs	700		800
Min. Pulse repetition rate	Hz	1		
Max. Pulse repetition rate	MHz	2		
Single pulse selection	MHz	up to 2		
Beam quality	M^2	<1.3		
Pulse peak power	MW	30	140	200
Beam diameter (1/e²)	mm	3.5 +/- 0.5		
Beam divergence (full angle)	mrad	<0.6		
Polarization		Linear horizontal		

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Trade Fair calendar

Options

- Available as integration module or integrated in control cabinet

Typical applications

- Cutting of materials like metals, plastics or brittle materials like glass or sapphire
- Drilling of different hole geometries (e.g. conical, elliptical etc.) with highest precision
- Structuring of materials in the µm-range
- Selective ablation of thin films in the nm-range without damaging other layers

Download

Datasheet StarFemto PDF (879 KB)

More ultrashort pulse lasers

- **More ultrashort pulse lasers for your specific application**

IRCameras

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1 July 2015

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

IRCameras, LLC (IRC) appreciates the opportunity to comment on the proposed changes to the USML.

<u>Introduction and Background Information:</u>
IRC is a manufacturer of infrared imaging systems and IDCAs (http://www.ircameras.com). The entirety of IRC's product lines are designed/offered as dual-use products but because of the "umbrella nature" of both the current and draft revisions of USML Category XII virtually all of our products are considered ITAR controlled. Even though this background is provided specifically for IRC, we expect that many other U.S. manufacturers of infrared imaging systems and IDCAs. IRC approached its review of, and response to, the Category XII re-write with the following primary concerns in mind:

- Was foreign availability given adequate consideration?
- Are parameters that define "specially designed for military use" called out?
- Has the playing field been leveled for U.S. companies when competing for foreign business while still maintaining the protection of our technological "crown jewels?
- Are the revised regulations written in a straightforward and user-friendly fashion?

There was a time when a good portion of the infrared imaging market was served by U.S. based manufacturers and providers. This being the case, one could argue that in spite of the dual-use nature of some of the technology/products available at that time the ITAR, and specifically Category XII of the USML, was appropriately written with the "umbrella nature" of its coverage. Due to the export restrictions the ITAR imposed, one significant by-product of the barriers to obtaining U.S. products/technology faced by the international community, including NATO and other close allies, has been the resultant development by that same international community of infrared technology and products that were previously available only, or predominantly in, the U.S. This has resulted in current foreign availability rivaling the U.S. in terms of capability in many areas. This is a significant development that IRC believes was not valued in developing the proposed Category XII re-write.

IRC, a small independently operating wholly-owned subsidiary of HEICO Corporation (http://www.heico.com), is just over four years old and is trying to establish a foothold in the ultra-competitive global marketplace that is infrared imaging systems. IRC offers itself as a reasonably priced alternative to the countless number of large providers, both international and domestic.

The following sections of this document will provide specific comments and suggestions for change that IRC hopes will result in a final re-write of the regulations that will address the above concerns and thus benefit and strengthen the entire U.S. infrared industry. It will make the U.S. more competitive and protect our Nation's technological leadership position.

Comments to specific Sections:

Section: XII(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optical, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:

Comments/Issues:

This title and the way it is written is confusing. The title should be written in such a manner that it provides a clear and solid foundation for how each of the following subsections should be understood and interpreted. For example, one of IRC's primary areas of interest is infrared imagers and imaging systems. When evaluating the following subsections which include, among other items, encapsulated IRFAs, unencapsulated IRFAs, and IDCAs, it is not clear if such items are to be addressed only as standalone items or as standalone items but also as part of an imaging system. Additionally, the terms "night vision, electro-optical, and equipment & accessories" are too vague and have no meaning in this context. Equipment & accessories should be addressed in Subsection (e).

We have chosen to address each of the following subsections separately for each item covered and not as part of an infrared camera, imager or imaging system. In addition, after addressing each of the existing subsections we have included a suggestion for addressing cameras, imagers and imaging systems as a separate new subsection.

Recommended changes:

Suggested revision to the proposed title language as follows:

"Section: XII(c) *Infrared focal plane array both encapsulated and unencapslated, image intensifier tubes, and IDCAs as standalone items, and separately the systems which such items are incorporated into including infrared cameras, imagers and imaging systems and terahertz systems;*

Section: XII(c)(4) Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanently encapsulated sensor assembly, having greater than 256 detector elements;

Comments/Issues:

1. Unless specially developed for military use and/or a military program the number of detector elements alone should not be a criteria for USML categorization as there is not awareness of a single example where this is the case.
2. With the qualification of #1 above noted, all detectors are inherently by default and definition, dual-use.
3. The following are three foreign sources for available dual-use permanently encapsulated (packaged) sensor assemblies:
   a. SCD
      http://www.scd.co.il/Templates/showpage.asp?DBID=1&LNGID=1&TMID=86&FID=1195http://www.scd.co.il/Templates/showpage.asp?DBID=1&LNGID=1&TMID=86&FID=1195
      http://www.scd.co.il/Pelican-D-LW
   b. Sofradir
      http://www.sofradir.com/category_product/mwir-detectors/
      http://www.sofradir.com/product/inspir-mw-2/
      http://www.sofradir.com/product/galatea-mw/
   c. IR-Nova
      http://www.ir-nova.se/products-mwir/

4. This section is silent on the source of the detector IRFPA. This is a key point in that IRC packages foreign manufactured IRFPAs, provided as Customer Furnished Equipment (CFE) by foreign customers, into permanently encapsulated sensor assemblies. Because the IRFPA is from a foreign source and the permanently encapsulated sensor assembly is often of a standard dual-use design, such items should not be ITAR controlled.

Recommended changes:

Revise the proposed rule as follows:

"Section: XII(c)(4) Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanently encapsulated sensor assembly, whereby either the U.S. manufactured detector IRFPA or the permanent encapsulation package is specially designed for military use".

Section: XII(c)(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

(i) Cryocoolers having a cooling source temperature below 218K and a mean-time-to-failure (MTTF) in excess of 3,000 hours:

(ii) Active cold fingers;

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b), (c) of this category;

Comments/Issues:

1. With regard to the cryocooler it is not known if cooling below 218K is related to military use. A standard MTTF of in excess of 3,000 hours alone cannot be specifically related to a military requirement as there are numerous dual-use applications (i.e. persistent surveillance, gas leak detection, etc.) that require cooler MTTFs far in excess of 3,000 hours. Further, the following foreign sources provide a wide array of cryocoolers with MTTFs in excess of 3,000:

   http://www.thales-cryogenics.com/product-category/coolers/
   http://www.aim-ir.com/en/main/products/cryocoolers.html
   http://www.ricor.com/

2. The definition of the term "Active cold fingers" is not understood outside of a military context. Therefore, unless its related to a specific military requirement, it results in confusion;
3. Dewar's are commonly designed for dual-use. It is not unusual that dual-use dewar designs are used in systems specially designed for military use. However, even in these cases, unless there is a specific parameter of a dewar design that is specially designed for military use, the dewar itself should not be ITAR controlled.

Recommended changes:

Revise the proposed rule as follows:

"Section: XII(c)(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

(i) A cryocooler designed specially for military use;

(ii) Variable or dual aperture mechanisms; or

(iii) Dewars designed specially for military use;

Section: XII(c)(12) Infrared imaging camera cores (e.g. modules, engines, kits), having any of the following:

Comments/Issues:

1. The title is overly broad and potentially confusing. If the intent is to address “cores”, then a core should be defined as part of the title to limit any confusion. Also, the words modules, engines and kits are subject to interpretation.
2. Is the reference to “specially designed electronics and optics” thereof, intended to indicate that electronics and optics are or can be included as part of a core? If a core does not include electronics or optics, is it not an IDCA?

Recommended changes:

1. Revised the proposed title as follows:

   “Infrared imaging cores consisting of IDCA (including IRFPA), electronics and optics (optional), having any of the following;”

   (i) An IRFPA designed specially for military use;

   (ii) A cryocooler designed specially for military use;

   (iii) Variable or dual aperture mechanisms;

   (iv) A Dewar designed specially for military use;

   (v) Electronics and/or software designed specially for military use; or

   ***Note:** Electronics in this context needs to be defined. Specifically, it is not understood what type of electronics would define a core versus a camera. If there is not a definition for electronics in the context of a core, then nothing differentiates a core from a camera and hence the term core and this entire section should be deleted from the regulations.*

   (vi) Optics designed specially for military use
2. If the title as written was not meant to convey that electronics and optics are part of a core, then move “electronics and optics” to Section XII(e).

Section: XII(c)(12) Infrared imaging camera cores (e.g. modules, engines, kits), having any of the following:

(iv) An IDCA described in paragraph (c)(9) of this category, or IDCA parts or components described in paragraph (e)(7) of this category:

Comments/Issues:

1. This proposed language inappropriately captures dual-use IDCAs. If an IDCA is classified as dual-use it should not be included as criteria for determining that a core that utilizes such an IDCA falls under USML classification.
2. As addressed in Comments to XII(c)(4) above, there are numerous foreign sources of dual-use IDCAs.

Recommended changes:

Revised the proposed title as follows:

"An IDCA having any of the following:

(i) An IRFPA designed specially for military use;

(ii) A cryocooler designed specially for military use;

(iii) Variable or dual aperture mechanisms;

(iv) A Dewar designed specially for military use;

Section: XII(c)(TBD) Infrared imaging cameras or camera systems, having any of the following:

Recommended changes:

As noted in of "Comments to specific Sections", in Comments/Recommendations to the Section 12(c) title, it is suggested that the following new subsection be added to Section XII(c):

"Infrared cameras, imagers and imaging systems having any of the following:

(i) An IRFPA designed specially for military use;

(ii) A cryocooler designed specially for military use;

(iii) Variable or dual aperture mechanisms;

(iv) A Dewar designed specially for military use;

(v) Electronics and/or software designed specially for military use; or

(vi) Optics designed specially for military use

As noted in the Background/Overview section of this document IRC's entire product line was developed and is offered as a suite of dual-use products. Even though some of our products may have military end-use, none of these products or their components were designed specially for military end-use. The following are links to the details of IRCs three main product lines:

Science Cameras:

http://www.ircameras.com/camera/broadband-ir-camera/
http://www.ircameras.com/camera/short-wave-900-series/
http://www.ircameras.com/camera/mid-wave-800-series/
http://www.ircameras.com/camera/mid-wave-900-series/

QuazIR™ Cameras for Mission Critical Continuous Operation applications:

http://www.ircameras.com/camera/quazir-hd-mwir-insb/

Niatros™ Cameras for Optical Gas Imaging applications"

http://www.ircameras.com/camera/niatros-optical-gas-imager/

The following table identifies foreign availability of products comparable to a number of products in IRC's product line:

Science Cameras			
IRC803 / IRC903 Science Camera			
Xenics Onca 320 MWIR	Belgium	320x256 InSb	http://www.xenics.com/en/onca-mwir-insb
IRCam Velox 147K	Germany	384x384 InSb	http://www.ircam.de/en/productnavigation/products/product-category/product-series/product-detail/product/velox-147k-m/prefillProductTitle/VELOX%20147k%20M/
IRC806 / IRC906			
Xenics Onca 640 MWIR	Belgium	640x512 InSb	http://www.xenics.com/en/onca-mwir-insb
IRCam Velox 327k	Germany	640x512 InSb	http://www.ircam.de/en/productnavigation/products/product-category/product-series/product-detail/product/velox-327k-sm-2/prefillProductTitle/VELOX%20327k%20SM/
InfraTec ImageIR8300	Germany	640x512 InSb	http://www.infratec-infrared.com/thermography/infrared-camera/imageirr-8300-series.html
IRC812 / IRC912			
IRCam Velox 1310 K	Germany	1280x1024 InSb	http://www.ircam.de/en/productnavigation/products/product-category/product-series/product-detail/product/velox-1310k-sm/prefillProductTitle/VELOX%201310k%20SM/
IRCam Velox 1310L	Germany	1280x102 QWIP	http://www.ircam.de/en/productnavigation/products/product-category/product-series/product-detail/product/velox-1310kl/prefillProductTitle/VELOX%201310k%20L/
InfraTec ImageIR9300	Germany	1280x1024 InSb	http://www.infratec-infrared.com/thermography/infrared-camera/imageirr-9300-series.html
QuazIR™ Cameras			
QuazIR™ 320			
Wuhan Guide IR131/133	China	320x256 MCT	http://www.guide-infrared.com/Content.aspx?lang=en&id=231

QuazIR™ Cameras(cont'd)			
QuazIR™ 320 (cont'd)			
Wuhan Guide IR-136	China	320x256 MCT	http://www.guide-infrared.com/Content.aspx?lang=en&id=47
Wuhan Guide IR267	China	320x256 MCT	http://www.guide-infrared.com/Content.aspx?lang=en&id=53
QuazIR™ SD InSB			
Selex Erica FF	Italy	640x512 MCT	http://www.selex-es.com/-/erica_ff-1
Xenics XCO-640	Belgium	640x512 T2 SLS, MCT or InSB	http://www.xenics.com/en/xco-640 Note on web site: "Made in Europe Easy to export with dual use export license - no ITAR restrictions"
Xenics Pumair 400	Belgium	640x512 T2 SLS, MCT or InSB	http://www.xenics.com/en/pumair Note on website: "Easy to export - no ITAR"
AIM MCT Arrays & Engines	Germany	640x512 MCT MW & LW	http://www.aim-ir.com/fileadmin/files/Data_Sheets_Modules/2011_neu/AIM_Data_Sheet_2nd-3rd-Gen.pdf
Opgal Eyelite	Israel	640x512 InSb	http://www.opgal.com/DEFENSE/DefenseProducts/OEMCameras/EyeLite.aspx
Controp Fox	Israel	640x512 InSb	http://www.controp.com/item/InfraRed-Camera-FOX-1400-Z

Niatros™ Gas Imaging Cameras			
Opgal Eye-C-Gas	Israel	320X240 InSb	http://www.eyecgas.com
KEII GL1000	China	320x240 T2 SLS	http://www.keii.com.cn/index.php?m=Product&a=show&id=73&l=en
KEII GL800	China	320x240 QWIP	http://www.keii.com.cn/index.php?m=Product&a=show&id=58&l=en

Because IRC's products contain no content or performance parameters designed specially for military use, and because there is significant comparable foreign availability for many of our products, we strongly believe that there should be a streamlined and less restrictive path to determine which infrared cameras, imagers and imaging systems fall under USML control.

Section: XII(e)(6) Vacuum packages or other sealed enclosures for an IRFPA or IIT controlled in paragraph (c) of this category specially designed for incorporation or integration into an article controlled in paragraphs (a), (b) or (c) of this category;

Comments/Issues:

1. Although a vacuum package or other sealed enclosure may be designed specially for incorporation of integration into an article controlled in paragraphs (a), (b), or (c) of this category, it is not clear what specific design parameters, if any, should be considered "controlled". For example, if a minor and innocuous dimensional change is made to an existing vacuum package design for incorporation into a controlled article, the vacuum package is by definition controlled even if incorporated into a non-controlled article. As a result, the general catch-all language renders the proposed paragraph impractical.

Recommended changes:

Revise the paragraph to include specific design parameters, including any parameter identified as "classified" by the U.S. military (e.g. spectral bandpass or cold shield design). This approach would seem to provide the level of protection of technology that is desired.

Section: XII(e)(7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components, as follows:

(i) Cryocoolers having a cooling source temperature below 218K and a mean-time-to-failure (MTTF) in excess of 3,000 hours;

Comments/Issues:

1. IRCameras is the U.S. Distributor for Thales (http://www.thales-cryogenics.com/product-category/coolers/). In this role we import cryocoolers from Thales' operations in both France and the Netherlands for resale and occasionally for export. Because these coolers are from a foreign source, even if certain of these cryocoolers met the parameters of this paragraph, this control should not apply.

Recommended changes:

Cryocoolers having a cooling source temperature below 218K and a mean-time-to-failure (MTTF) in excess of 3,000 hours (10,000-30,000 hours seems to be standard), unless obtained from a foreign source and not manufactured in the U.S. or with the use of U.S. technology;

Section: XII(e)(9) Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category;
(10) Drive, control, signal or image procession electronics, specially designed for articles controlled in this category;

Comments/Issues:

1. It is possible, and in some cases highly probable, that the items covered in these two paragraphs may be specially designed for dual-use but can also be included in systems

specially designed for military use. If by definition, this would qualify the item as non-USML then this point is moot and this is not an issue.

Recommended changes:

To avoid confusion or misinterpretation the language should be revised as follows:

(9) Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed *only* for any article controlled in this category;

(10) Drive, control, signal or image procession electronics, specially designed *only* for articles controlled in this category;

Summary of Comments to Sections XII(c) and (e):

At only four years old IRC is still trying to establish itself in the hyper-competitive landscape that is the global infrared marketplace. Establishing that foothold is difficult enough for a small company, but when the foreign segment of the marketplace comes with built-in barriers due to export restrictions, real or perceived, to all but foreign competitors, staying competitive and being able to grow or even remain viable as a going concern, can be potentially insurmountable. IRC's comments and recommendations are structured to be user friendly.

Currently, approximately 90% of IRC's business is non-military. This is a testament to the dual-use nature of our product line. This business is largely domestic. IRC estimates a 30% increase in revenue with more ready access to foreign markets resulting from relaxed and/or clearer export regulations. It is important to note that when dealing with the current regulations, with the same being the case with the proposed draft language, we are faced with both real and perceived restrictions when it comes to potential foreign customers. It is well understood that many foreign customers and entities understand, or think they understand, the ITAR better or at least as well as many of their U.S. counterparts. As such, they are making purchasing decisions, both tactical and strategical, based on their understanding and interpretation of the current regulations. Because of the lack of a "bright line" in the regulations that clearly delineates dual-use from specially designed for military applications/purposes, potential foreign customers are likely making purchasing decisions either dismissing or not even considering U.S. sources. They are making these decisions because: a) they have independently determined that a product may not be exportable, rightly or wrongly; b) they do not consider a U.S. source because they do not understand or do not want to understand the complexities of the ITAR as they currently exist or; c) they cannot or do not want to deal with the amount of time it takes to determine a product's exportability and obtain a license and/or then potentially have that license denied. In addition to having to overcome the obstacle that is the ITAR when competing with foreign sources for dual-use product based business (believed to be significant), due to the ITAR impediment, U.S. companies are not able to compete for foreign opportunities on equal footing. Revising the export controls by incorporating the "bright line" philosophy between dual-use items and those designed specially for military applications in a reasonable and straightforward manner will level the playing field for U.S. companies when competing with foreign entities for the sale of products that should not be ITAR controlled. Should this approach be adopted, it will provide opportunities for growth for large and small companies alike, and will lead to a stronger U.S. industry overall that will result in all the positive things that come along with it, such as increased employment, etc.

It is realized that along with items that are specially designed for military use, and the parameters that define them, there is certain technology that is uniquely available in the U.S. that may or may not have been developed specially for military use, but that wants to be controlled via the USML. The overriding recommendation in both of these cases is that the entirety of the regulations should be revised such that these items and parameters, whatever they are, should be positively identified in the regulations. This approach will eliminate confusion and the potential for misinterpretation. The current structure and philosophy of passive catch-all phrasing which requires the users of the regulations to interpret and determine which technologies and parameters, and hence products, fall under USML control, is difficult to deal with, leads to faulty decision making by both U.S. industry and the foreign customer base. It also places U.S. companies at a competitive disadvantaged when competing for foreign business.

We appreciate the work that the administration has put into the effort of trying to improve the export controls and as well as the opportunity given to provide comment. However, we do not believe the four concerns identified in the Background/Overview section above have been adequately addressed in the proposed re-write of the regulations. We encourage the administration to give these comments and recommendations due consideration for inclusion into the final rewrite of Category XII of the USML. Thank you for you continued efforts.

If you require any further information or have any questions about any of the above, please contact me at 805-452-8297 or via email at greg.smoyer@ircameras.com.

Sincerely,

Greg Smoyer
Vice President
IRCameras, LLC

IRRADIANCE
GLASS

Comments for proposed rules **Category XII** of the USML and **Category 6** of CCL
on sections applicable to IRradiance Glass, Inc (IRG)

Prepared by: Jennifer McKinley, COO, IRradiance Glass
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321-250-8200 x200

Category XII Comments

1. **Direct comparison of non-military products with USML entries**

No comments

2. **Assessment of the appropriateness of the parameters and thresholds chosen to designate USML items**

Agree with (e) (9), although there should be more clear guidance for DoD-funded development (e.g. SBIR/STTR) contract development to state when an item is being developed for dual-use (perhaps a checklist of documentation requirements and contract language would be helpful). Details of this guidance could be communicated to DoD SBIR/STTR topic authors, research institutes, and recipient companies of DoD-funded development contracts and awards.

Agree with (e) (15), per executive order 13526

3. **Assessment of the overall scope of controls on the USML**

Agree that Category XII revisions applicable to IRG place "higher walls around fewer items", "enhance industrial base (as long as dual-use development is clear), and "has clear, straightforward guidelines."

4. **Address whether the proposed rules, in total, creates an environment in which US companies can successfully compete**

See comments above for dual-use development

5. **Do the proposed rules follow the ECR guidelines?**

See comments on item 3 above.

Index

Commercial Space and United States National Security

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Prepared for the Commission to Assess United States National Security Space Management and Organization

The information presented in this paper is based on research done by the author. Although it was prepared for the Commission in conjunction with its deliberations, the opinions expressed in this paper are those of the author alone and do not represent those of the Commission or any of the Commissioners.

I. Introduction

Commercial satellite services are important to United States (U.S.) national security in several ways. Commercial satellites provide services and products to the U.S Government for defense and intelligence missions.(1) Commercial satellites are part of the nation's critical telecommunications infrastructure and support many other U.S. critical infrastructures, including banking, finance and transportation.(2) In addition, commercial satellites are integral to daily life and commerce.

Commercial satellites enable U.S. companies to participate in the market, teachers to educate the nation and farmers to grow America's crops. From residents at the base of the Grand Canyon(3) to explorers at the South Pole,(4) satellites deliver communications, information, navigation, Internet, rescue,(5) disaster relief, emergency(6) and other services to people, businesses and organizations.(7) In these regards, the U.S. commercial space sector contributes to the strength of the U.S. economy and to the position of the United States as the world leader in space.

As described below, the United States relies heavily on commercial space services and technologies. That reliance likely will magnify as information and communications become more integral to U.S. defense and intelligence missions and more imbedded in American commerce and activity.(8) With reliance comes vulnerability. At the same time, commercial satellite services provide means for adversaries to act against the interests of the United States, posing national security risks. Commercial space, however, also presents opportunities. It offers faster, innovative technologies and services, increasing efficiency and broadening the types of applications. Commercial satellites provide the means for the United States to advance and protect--at home and abroad--the principles upon which this country was formed and stands today.

This paper provides background research for the Report of the Commission to Assess U.S. National Security Space Management and Organization (Commission).(9) In 1999, Congress chartered the Commission, directing it to assess U.S. national security space, including management and organization changes that could strengthen U.S. national security.(10) In its assessment, the Commission identified four space sectors: defense, intelligence, commercial and civil. The Commission considered the role of the commercial space sector in the United States and the world, including the growing interdependence of the four sectors and the rise in international space programs. The Commission studied the extent to which the United States relies on space, and the ensuing vulnerabilities, risks, threats and opportunities arising from that reliance. The Commission assessed opportunities for the U.S. Government to use the commercial space sector for national security space functions. Finally, the Commission studied ways to leverage the commercial space sector to strengthen U.S. national security.

This paper describes four types of satellite services: (1) remote sensing satellite services; (2) location, navigation and timing satellite services; (3) communications satellite services; and (4) weather satellite services.(11) The paper discusses the principal commercial applications of each service, its technological characteristics, financial value and expected growth, as well as national security implications. The paper also discusses global business trends, U.S. and international legal and regulatory issues and interagency coordination. In addition, the paper addresses U.S. use of commercial satellite services and products for defense and intelligence missions.

This paper is a survey of commercial satellite applications and developments. It intends to provide an overview of the four satellite services rather than a comprehensive treatment of the commercial space sector. References to particular companies and countries are to illustrate satellite applications and trends; omission of others is unintentional. This paper is based on multiple sources. In addition to the research that the paper cites, resources include: briefings before the Commission to Assess National Security Space Management and Organization, interviews with more than 50 U.S. Government and industry members, including representatives of the National Security Council (within the Defense Policy and Arms Control Directorate), Office of Science and Technology Policy (within the Division of Technology), Department of Defense,(12) Department of State,(13) Department of Commerce,(14) Department of Transportation (Coast Guard), Department of Justice (Criminal Division), Federal Bureau of Investigation (Office of

General Counsel), Federal Communications Commission,(15) Wall Street financial firms, satellite companies and private entities. The factual information below attempts to be as current and accurate as possible as of the time of publication. Given the dynamic nature of the commercial satellite industry, however, it is possible that information may have changed since that time.

II. Background

A. U.S. Leadership in Space through Government and Commercial Enterprise

1. Origins of the U.S. Commercial Space Sector

The U.S. space industry has evolved into four sectors. These are: the defense, intelligence, commercial and civil space sectors. Since the start of U.S. space activities decades ago, the vision and efforts of scientists, entrepreneurs, private companies and government officials have made the U.S. space sectors what they are today. The world lead of the United States in space is the result of U.S. Government and commercial enterprise.

In 1919, an American scientist, Robert H. Goddard, published a landmark paper that established the foundation for the development of U.S. rockets.(16) On October 13, 1936, an Army Air Corps Lieutenant met with Dr. Goddard to assess military applications of Goddard's study. In 1945, Arthur C. Clarke first wrote of geosynchronous satellites. A 1946 RAND Corporation study predicted that earth satellites would "inflame the imagination of mankind, and would probably produce repercussions in the world comparable to the explosion of the atomic bomb."(17) On October 1947, a U.S. Navy V-2 rocket took the first photograph of the Earth from an altitude of 100 miles.

In 1958, Congress formally established a civilian space agency in the "National Aeronautics and Space Act of 1958." The Act established the National Aeronautics and Space Administration (NASA) as a civilian agency to develop a comprehensive program for research and development in aeronautical and space services.(18) In addition, the Act provided for development of space technology for civilian applications such as communications satellites and sought "the preservation of the role of the United States as a leader in aeronautical and space science and technology."(19)

Four years later, in the Communications Satellite Act of 1962 (Satellite Act), Congress laid the foundation for the world's first global communications satellite system.(20) Congress declared that "it is the policy of the United States to establish, in conjunction and cooperation with other countries, as expeditiously as practicable, a commercial communications network, which will be responsive to the needs and national objectives, which will serve the communications needs of the United States and other countries, and which will contribute to world peace and understanding."(21) Eventually, that global satellite system became the International Telecommunications Satellite Organization (INTELSAT) system.(22)

INTELSAT began as an intergovernmental, treaty-based satellite organization of thirteen members and one geosynchronous satellite. INTELSAT, which now has 144 members and approximately 20 satellites, will become a private company in July 2001.(23) In the Satellite Act, Congress established COMSAT as the first private U.S. satellite corporation to operate for profit.(24) Congress created COMSAT to facilitate development of the global INTELSAT system and to provide for the widest possible participation by private enterprise in that system.(25) INTELSAT launched its first satellite, Early Bird, in 1965. As an initial commercial satellite provider, INTELSAT benefited from U.S. taxpayer-funded research and development conducted in the pioneering days of space communications. (26) INTELSAT also benefited from government policies designed to assure its early commercial success so as to achieve the broader public policy goals intended by its creation.(27)

After the INTELSAT global system was operating, the United States began to explore the possibility of authorizing "domestic" satellite systems to serve the United States. On January 23, 1970, the Executive Office of the President submitted a memorandum to the Federal Communications Commission (the independent U.S. agency responsible for licensing communications systems) setting forth several satellite policy objectives, many of which still apply:

- Assuring full and timely benefit to the public of the economic and service potential of satellite technology.
- Fostering widespread awareness about the possibilities for satellite services.
- Minimizing regulatory and administrative impediments to technological and market development by the private sector.
- Encouraging more vigorous innovation and flexibility within the communications industry to meet a constantly changing range of public and private communications requirements at reasonable rates.
- Discouraging anticompetitive practices that inhibit growth of healthy communications and related industries.
- Ensuring that national security and emergency preparedness needs are met.(28)

The Executive Office of the President recommended:

> It is most important that the establishment and operation of domestic facilities be consistent with our obligations and commitments to Intelsat and the International Telecommunication Union, with other foreign policy considerations, and with national security communications requirements.... It also is important that provision be made for use of domestic satellite services by national security and emergency preparedness agencies when appropriate.(29)

Two months later, the Federal Communications Commission issued its landmark Domsat I decision. That decision and its sequel, Domsat II,(30) gave birth to the U.S. satellite industry. In those orders, the Federal Communications Commission established its "Open Skies" policy--the hallmark of U.S. satellite policy today. The Federal Communications Commission found that satellite technology has the potential of making significant contributions to the nation's domestic communications structure by providing a better means of serving existing markets and developing new markets not now being served. The Open Skies policy was based on the agency's conclusion that the public interest would best be served at this initial stage by affording a reasonable opportunity for entry by qualified applicants. The agency established a framework of maximum flexibility and minimal regulation. Recognizing as well the uncertainties regarding the potential success of commercial communications satellites and the availability of other terrestrial alternatives, the Federal Communications Commission let market forces and competition drive the satellite industry. It opened the U.S. satellite market to any number of satellite operators to provide any type of domestic satellite services in the United States. A competitive U.S. satellite industry subsequently developed, contributing substantially to the strength of the United States in the global satellite market.

The U.S. Government has continued to play a substantial role in facilitating a competitive global satellite market and influencing the direction of INTELSAT. After recognizing the benefits of a global satellite telecommunications system and the benefits of U.S. participation in such a system by creating the framework for INTELSAT, in the 1980s-90s, the United States and other governments authorized other communications satellite systems to introduce competition in the international satellite market.(31) After those systems became operational and eventually more competitive, in the mid-1990s, the U.S. Government undertook efforts to encourage INTELSAT to become more competitive as well, recognizing the strong public interest benefits that would result. "The privatization of INTELSAT is a policy goal of the United States."(32)

As discussed in Section V. below, in response to competition and the interests of governments for a more competitive satellite market, INTELSAT inaugurated a multi-year effort to restructure. In 1998, INTELSAT spun-off five satellites to a separate entity, New Skies Satellites, N.V., which is based in the Netherlands and now competes with INTELSAT.

In March 2000, Congress passed the "Open Market reorganization for the Betterment of International Telecommunications Act" (ORBIT), establishing competitive criteria for the full privatization of INTELSAT in order to serve the U.S. market.(33) Thereafter, in August 2000, the Federal Communications Commission authorized INTELSAT to operate in the United States effective upon its privatization, and conditioned upon compliance with ORBIT.(34) The agency took this forward-looking action to "promote competition in the provision of satellite communications services through the privatization of INTELSAT in a manner consistent with U.S. law."(35)

This history shows that the development of U.S. space assets is the result of a strong connection between government and industry. That connection has benefited both, as well as the public overall. U.S. industry has profited from U.S. Government research and technology. At the same time, the U.S. Government has relied on commercial satellite services and products for numerous defense and intelligence purposes over many years. For example, the U.S. Government used commercially developed direct broadcast television technology in conceptualizing its Global Broadcast Satellite system and used commercial remote sensing data in Desert Storm. Since the inauguration of U.S. space efforts decades ago, the four space sectors have been linked. As delineated below, today, they are becoming increasingly interdependent.

2. Commercial Space Sector

The space industry is transforming and growing. In the past, the manufacturing and launch components of the industry were strong segments. That strength, however, is shifting to satellite services. For example, over the last decade, the U.S. defense industry generally has been operating at flat levels.(36) The growth rate for manufacturers of launch vehicles and satellites "has been relatively flat" while ground segment industry "has been a source of tremendous growth."(37) For example, in its *Satellite Communications 2001 Outlook and Investment Guide*, C.E. Unterberg, Towbin ranks manufacturing and launch services segments lower than most other segments of the commercial communications satellite industry.(38) One prediction is that infrastructure and manufacturing, which represent about half of space industry revenues, will grow minimally in the next five years.(39)

At the same time, the satellite industry is growing in both the United States and worldwide. The Satellite Industry Association estimates that 2000 worldwide revenues for the commercial satellite industry will be $82.6 billion.(40) This figure, which includes commercial communications satellite services, launch services, manufacturing of satellites and of ground equipment, as well as sale of remote sensing imagery and value-added services, represents nearly a 100% increase since 1996 when global satellite industry revenues were $44.8 billion.(41) According to the Satellite Industry Association, U.S. satellite industry revenues represent nearly half of worldwide revenues: an estimated $37.5 billion.(42) That amount is nearly twice U.S. satellite revenues in 1996: $19.6 billion.(43) One prediction is that satellite services and applications will more than double by 2005, representing more than two-thirds of space industry revenues.(44) ING Barings estimates that global commercial satellite service revenues will more than triple by 2009.(45)

Several factors influence the viability and growth potential of particular commercial satellite services. These are for example: technology, cost, competing services, regulatory policies and the economy.(46) The technical ability of satellites to cover large geographic areas and to provide views from space, make satellites advantageous for several applications. For example, and as elaborated in Section V. below, communications satellites offer these technological advantages and economic efficiencies:

- Instant infrastructure: Once a satellite is launched, it can serve millions via a few ground stations.
- Cost efficiency: Satellites avoid the cost and difficulty of laying fiber especially in geographic areas with rough terrain or small populations.
- Simultaneous access: Satellites can allow satellite companies to reach many customers at once, regardless of distance or geography.
- Point-to-multipoint: Through satellite networks such as VSATs (Very Small Aperture Systems), which use a "hub" design, information can be distributed from one central source to many distant locations. For example, a U.S. corporation can set up offices in foreign countries, including those with inadequate telecommunications infrastructure, and communicate with a home office in the United States.

Availability of competition from other services and technologies has a substantial impact on the satellite industry. For example, at this time, imagery from airplanes represents the largest part of the imagery market. Remote sensing satellites, however, can see much larger areas of the earth than that visible from airplanes and are equipped to produce images of higher resolution. Another example of the varying viability of satellite technology is the U.S. Global Positioning Satellite (GPS) System. The timing feature of the GPS system has wide commercial, government and societal applicability. To date, however, there is no comparable timing capability available in the world.

By contrast, there are numerous telecommunications services available and many provide strong competition to commercial satellite communications services. As described in more detail in Section V. below, competition is stronger against certain types of communications satellite services than others, based largely on technology, demographics and cost. For example, the satellite telephony market, particularly the global mobile market, has had difficulty competing with terrestrial wireless services. Generally cheaper and quicker to build and install than satellite systems, cellular telephone systems have been deployed rapidly and widely around the globe.

B. U.S. National Security Space Policies

Space is becoming increasingly important in U.S. national security strategy. U.S. forces must have information superiority in every mission area and assured access to and use of space.(47) The *1999 National Security Strategy* states that:

> We are committed to maintaining U.S. leadership in space. Unimpeded access to and use of space is a vital national interest--essential for protecting U.S. national security, promoting our prosperity and ensuring our well-being.... We will maintain our technological superiority in space systems, and sustain a robust U.S. space industry and a strong, forward-looking research base. We also ... will continue to pursue global partnerships addressing space-related scientific, economic, environmental and security issues.(48)

The *1999 U.S. National Security Strategy* provides that "vital interests" of the United States include: "the economic well-being of our society, and the protection of our critical infrastructures--including energy, banking and finance, telecommunications, transportation, water and systems and emergency services."(49)

In September 1996, President Clinton issued the *National Space Policy*.(50) It establishes five U.S. goals:

> (1) Enhance knowledge of the Earth, the solar system and the universe through human capital and robotic exploration;
>
> (2) Strengthen and maintain the national security of the United States;
>
> (3) Enhance the economic competitiveness, and scientific and technical capabilities of the United States;
>
> (4) Encourage State, local and private sector investment in, and use of, space technologies;
>
> (5) Promote international cooperation to further U.S. domestic, national security, and foreign policies.(51)

The *National Space Policy* declares that the United States "will conduct those space activities necessary for national security"(52) and that "[c]ritical capabilities for executing national security missions must be assured."(53) It provides that the "fundamental goal of U.S. commercial space policy is to support and enhance U.S. economic competitiveness in space activities while protecting U.S. national security and foreign policy interests. Expanding U.S. commercial space activities will generate economic benefits for the Nation and provide the U.S. Government with an increasing range of space goods and services."(54) The *National Space Policy* also states: "U.S. Government agencies shall purchase commercially available space goods and services to the fullest extent feasible and shall not conduct activities with commercial applications that preclude or deter commercial space activities except for reasons of national security or public safety."(55)

C. National Security Implications of Satellite Infrastructure

1. U.S. Critical Infrastructure

Commercial satellites are part of the U.S. critical infrastructure. The 1998 *Critical Infrastructure Protection Policy* (Presidential Policy Directive 63) defines "critical infrastructures" as "those physical and cyber-based systems essential to the minimum operations of the economy and government."(56) "They include, but are not limited to, telecommunications, energy, banking and finance, transportation, water systems and emergency services, both governmental and private." (57) The "telecommunications" infrastructure, also called the "information and communications" infrastructure, includes "satellite service."(58)

According to the 1997 President's Commission on Critical Infrastructure Protection, the U.S. communications and information infrastructure sector:

> generates more revenue than most nations produce.... We have led the world into the information age, and in so doing have become uniquely dependent on its technologies to keep our economy competitive, our government efficient, and our people safe. (59)

As a result, the sector "has swiftly become essential to every aspect of the nation's business, including national and international commerce, civil government, and military operations."(60) Thus, like highways and airways, water lines and electric grids, services supplied from space already are an important part of the U.S. and global infrastructures. As such, they raise national security considerations.

The *Critical Infrastructure Protection Policy* established a program to assure the continuity and viability of U.S. critical infrastructures. This policy set a national goal that by 2000, the United States shall have achieved an "initial operating capability" and no later than by 2003, the United States shall have achieved and shall thereafter maintain the ability to protect our nation's critical infrastructures from intentional acts that would significantly diminish the abilities of:

- the federal government to perform essential national security missions and ensure public health and safety;
- state and local governments to maintain order and deliver minimum essential public services;
- the private sector to ensure the orderly functioning of the economy and the delivery of essential telecommunications, energy, financial and transportation services.(61)

As the 1997 President's Commission on Critical Infrastructure Protection found, the nation's critical infrastructures have become more interconnected and vulnerable. While in the past, many of these systems were physically separate, as a result of advances in information technology and greater efficiency, today, many of the systems are more automated and interdependent. For example, the nation's electrical energy infrastructure is linked to the communications infrastructure: the distribution portion of the bulk power grid involves telecommunications networks, including satellite systems.(62) The country's air transportation infrastructure is linked to satellites: modernization of the National Airspace System will depend on GPS and GPS augmentation as its sole navigation and landing systems.(63)

The interdependence of U.S. critical infrastructures has "created new vulnerabilities to equipment failures, human error, weather and other natural causes, and physical and cyber attacks."(64) For example, "Possible exclusive reliance on GPS and its augmentations, combined with other complex interdependencies, raises the potential for 'single point failure' and 'cascading effects.'"(65) As the *Critical Infrastructure Protection Policy White Paper* states:

> Because of our military strength, future enemies, whether nations, groups or individuals, may seek to harm us in non-traditional ways including attacks within the United States. Our economy is increasingly reliant upon interdependent and cyber-supported infrastructures and non-traditional attacks on our infrastructure and information systems may be capable of significantly harming both our military power and our economy.(66)

Addressing those vulnerabilities "will necessarily require flexible, evolutionary approaches that span both the public and private sectors, and protect both domestic and international security."(67)

2. Satellite Infrastructure

Security and Reliability

Like most U.S. infrastructure, satellites and their supporting systems are susceptible to a variety of security and reliability risks. These include, but are not limited to:

- Physical attacks of facilities and ground stations.
- Cyber attacks on ground networks.
    - Mechanisms to remotely access, change or destroy information in vulnerable systems and to damage, control or shut down systems have become more available, sophisticated and easier to use.
- Large numbers of computer-based attacks are not detected.
- New entrants and multinational alliances.
    - Technical details of systems are widely available.
    - Introduction of numerous third parties, including foreign companies operating in partnership with U.S. companies.(68)

Satellites may malfunction. For example, in May 1998, the Galaxy IV satellite suddenly malfunctioned, shutting down 80% of the nation's 40-45 million pagers, as well as video feeds for cable and broadcast transmissions.(69) At that time, paging companies, which have operated on lower margins than networks and thus, had less back-up capability, took weeks in some cases to fully restore paging service because thousands of ground antennae had to be repointed to other satellites. With greater redundancy measures available, the networks were able to switch relatively quickly to other satellites.

There are mechanisms to address system failures. Satellite systems generally include replacement satellites that can be launched or moved into the orbit of an inoperable satellite. In addition, innovative backup options are emerging. For example, a new U.S. company, AssureSat will offer on-orbit back-up capacity for lease to companies in need of substitute or additional capacity.(70) Hughes Global Services is reconfiguring satellites for new owners that do not need the same level of capability as a satellite's original owner.(71) This type of service will provide important safeguards and minimize the effects of service outages and delays. It also will provide financial benefits to the satellite industry because most satellite insurance covers only the book value of the hardware and does not cover losses due to lack of service.

III. Remote Sensing Satellite Services

A. Background

Remote sensing satellites operate by detecting various forms of electromagnetic radiation reflected from objects near the surface of the earth. The satellite sensors receive visible light (optical), thermal (infrared), or radio waves (radar). Optical sensors provide images that are similar to eyesight and therefore are more easily interpreted by humans. Optical sensors require that a satellite pass over an area during sunlight and in cloud-free atmospheric conditions. Infrared sensors are capable of detecting thermal radiation in darkness but are hampered by cloud cover. Radar sensors require neither sunlight nor cloud-free conditions and are not affected by water vapor in the atmosphere.(72)

The resolution of the images produced by remote sensing satellites depends on the quality and type of sensors. The latest generation of commercial remote sensing satellites is capable of producing panchromatic images of less than one-meter resolution. Through such high-resolution images, one can identify objects on the ground that are the size of vehicles. By comparison, the best available imagery from older remote sensing satellites was slightly more than five-meter resolution. Through those images one could detect only larger objects the size of bridges and roads.

Satellite imagery has been available publicly through the U.S. Landsat program since 1972. Since then, the United States has made available for civil purposes remote sensing imagery and data from its Landsat satellites, first operated by NASA and later transferred to the National Oceanographic and Atmospheric Administration (NOAA).(73) After passage of the Landsat Commercialization Act of 1984, the U.S. government privatized the Landsat program, which eventually failed.(74) In the 1992 Land Remote Sensing Policy Act, the Landsat program was transferred back to the U.S. government.(75) In 1994, Presidential Decision Directive 23 gave NASA, NOAA, and the U.S. Geological Survey joint responsibility over the Landsat program.(76) Until the mid-1990s, Landsat, Spot Image and the Indian Space Research Organization (ISRO) were the only sources of commercial satellite imagery.

At present, aerial imagery, rather than satellite imagery, has the largest share of remote sensing revenues.(77) The satellite remote sensing segment, however, is expected to grow at a faster rate than the aerial segment. (78) Industry analysts expect that over 40 remote sensing satellites will be launched in the next decade.(79) Frost & Sullivan estimated that the remote sensing sector generated about $2.3 billion in revenues in 1998 and expects revenues to reach $5.1 billion by 2004.(80) Governments are the main customers of remote sensing products and this trend is likely to continue as commercial high-resolution satellite imagery becomes available at lower costs.(81)

There have been two key technological advances in satellite remote sensing in the last decade: higher resolution and smaller satellites. For example, prior to the launch of Space Imaging's Ikonos satellite, the best commercially available imagery was six-meter panchromatic resolution imagery produced by the Indian IRS series of satellites. Higher resolution improves the image and broadens its possible uses. Reduction in the size of satellites is significant because it lowers launch costs. For example, earlier remote sensing satellites weighed between 1,000- 2,000 kg and typically cost between $300 million and $350 million per satellite to manufacture and launch. Newer satellites weigh between 68-720 kg and can be launched on less powerful rockets for under $150 million, including manufacturing costs.(82)

B. Commercial Applications

There are a number of commercial applications for satellite remote sensing. These include for example, agriculture, civil and urban planning, environmental and pollution monitoring, geological exploration, forestry, insurance and terrestrial mapping. In agriculture, remote sensing satellites enable identification of insects, disease and irrigation problems. Remote imagery can assist local governments with urban planning, property appraisal, emergency planning and response, and infrastructure management. Color and near-infrared images have been used to identify vegetation species and land cover and to measure environmental factors that could affect ecosystems. The insurance industry is another market for satellite remote sensing. Property loss evaluation and risk assessment problems also lend themselves well to satellite imaging solutions.(83)

Exploration of oil, gas, and mineral deposits is a major market opportunity for the commercial remote sensing industry. As the current sources of supply of natural energy deposits decreases, governments and corporations will continue to seek new methods to identify and locate large supplies of natural energy resources. Oil and gas deposits can be identified by combining imaging products with other types of geological data such as seismic assessments and geological interpretations. Mapping also may improve from remote sensing applications: one meter spatial resolution satellite data would close the gap between satellite imaging products and the aerial photographs currently being used for smaller scale mapping.(84)

Some companies are exploring the commercial market for satellite-based radar remote sensing. Unlike visual imagery, which requires sensors to detect light reflected off objects on the earth's surface, radar signals are unaffected by cloud cover and darkness. Radar signals thus enable the satellite to obtain images 24 hours a day in atmospheric conditions that otherwise would render most other types of imaging satellites useless.

Spot Image has estimated that commercial radar imagery generated about 15% percent of the global market revenues in the satellite imagery segment in 1999.(85) The prospects for a large commercial market, however, are uncertain at this time. The current generation of radar remote sensing satellites in orbit is more applicable for scientific and geologic purposes than for commercial purposes. For example, radar imagery may be used to monitor glacial movements(86) to map regions such as rain forests where cloud cover is a problem and to conduct environmental monitoring.(87)

A number of governments and companies in the United States, Canada and Germany have plans to launch commercial satellites with high-resolution radar sensors within the next few years. In June 1998, the Department of Commerce issued the first-ever license to build and operate a commercial radar imaging satellite to RDL Space Corporation.(88) In November 2000, however, RDL surrendered its license after NOAA alleged that the company committed government-contract fraud.(89) NASA is attempting to finance and build a radar imaging satellite.

Canada's Radarsat 1 satellite contains synthetic aperture radar sensors with ground resolution capabilities of about 10 meters. A second Radarsat satellite with ground resolution capabilities of its SAR sensors to three meters is scheduled for launch in 2002. European companies, with assistance from European governments, are designing a radar imaging satellite predominantly for commercial applications.(90) One such program consists of a two-satellite system, called TerraSAR, being designed by the German Aerospace Center (DLR industry, DASA) (now part of the Franco-German-Spanish industrial consolidation in EADS), the British National Space Center and Matra Marconi Space U.K. The satellites, tentatively scheduled for first launch in 2004, reportedly will carry X-band and L-band radars capable of producing images with a resolution of one meter.(91)

C. Remote Sensing Satellite Programs and Companies

1. United States

U.S.-based companies began to enter the commercial satellite imaging market in the mid-1990s. It has taken longer than anticipated to deploy remote sensing satellite systems because of regulatory issues, funding considerations and technical problems. Today, EarthWatch Inc. and Space Imaging offer one-meter resolution imagery.(92) In 2001, Orbimage plans to launch a one-meter resolution satellite and the world's first hyperspectral imaging satellite.(93)

In December 2000, the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), which licenses the operation of remote sensing satellites in the United States, authorized Space Imaging and Earth Watch to provide half-meter imagery--the highest resolution imagery ever authorized in the United States.(94) Space Imaging plans to provide half-meter imagery in 2004, when it launches a second satellite. Under U.S. regulation, however, commercial providers cannot release half-meter imagery until 24-hours after it is obtained. The purpose of the restriction is "to mitigate concerns that foreign governments could use the photographs to conduct military operations against U.S. forces."(95)

2. Foreign Programs and Satellite Systems

Several foreign countries currently have or are developing remote sensing capabilities. Among these, France, Japan, India, Israel, Russia and China/Brazil have the most substantial capabilities. More than 20 nations plan to launch their own remote sensing satellites by 2005.(96)

France is a strong foreign player. With cooperation from Belgium and Sweden, beginning in 1982, the French space agency *Centre National d'Etudes Spatiales* (CNES) developed the Spot Image remote sensing satellite system.(97) The Spot program now includes commercial satellites capable of providing panchromatic images at 10-meter resolution,(98) sensors for vegetation and biosphere applications and a Pastel optical terminal that can provide intersatellite laser connectivity.(99) Spot Image's customers include military users.(100)

U.K.-based Surrey Satellite Technology Ltd. is building a "Disaster Monitoring Constellation" (DMC). The system consists of five satellites that will provide satellite coverage of participating countries affected by disaster once every 24 hours. The Surrey system will offer 36-meter resolution images from satellites at 425-mile polar orbits. The British government and Algeria have announced that they will acquire the first two DMC satellites.(101)

The Japanese government has supported the development of indigenous satellite technologies, even while it has continued purchasing images from companies in the United States and elsewhere.(102) The Japanese government continues to fund satellite development by Japanese companies despite the fact that those satellites cost about 50% more than similar U.S. satellites.(103)

The Indian Space Research Organization, which was established in 1972, monitors India's remote sensing satellite programs. Following its first launch in 1987, India now has four Indian Remote Sensing (IRS) satellites in orbit. Its most advanced in orbit IRS satellite is capable of producing panchromatic images at about six-meter resolution.(104) India plans to launch a series of remote sensing satellites through 2003, which include the IRS-P6 with a reported 2.5-meter resolution capability.(105) India's commercial activities for its remote sensing satellites include distribution relationships with EOSAT in Norman, Oklahoma and Euromap, a subsidiary of GAF located in Munich, Germany.(106)

Although many of the Israeli remote sensing programs are military in nature, the Israel Space Agency, founded in 1983, has conducted a significant amount of research and other such activities with American and European partners in the area of civil space. The Eros satellite program is being developed through West Indian Space, a joint venture between IAI and Core Software Technology of Pasadena, California.(107) The Eros satellites will have resolution capabilities of about one meter in the panchromatic range, making them competitive with those offered by U.S.-based companies.(108) Russian remote sensing satellites purportedly are capable of mapping the earth's surface at one-meter resolution.(109) According to the Russians, the electro-optic cameras aboard its satellites can cover 60,000 square kilometers of the earth's surface with one picture, a capability, they claim, that U.S. cameras do not possess.(110)

In 1988, China and Brazil established a joint program to cooperate on the development of an earth resources satellite. In October 1999, China and Brazil launched the ZY-1 satellite with 20-meter resolution (111) and in 2000, the ZY-2 satellite.(112)

D. National Security Implications

The commercial satellite remote sensing sector has important implications for U.S. national security--both as challenges and opportunities. The objective of Presidential Decision Directive 23 is "to support and enhance the U.S. industrial competitiveness in the field of remote sensing space capabilities while at the same time protecting U.S. national security and foreign policy interests."(113)

Foreign suppliers such as Spot Image of France have an established market for imagery data from their commercial satellite operations. The Japan NASDA ALOS (Advanced Land Observation Satellite),(114) a mapping and environmental research applications satellite with resolution in the 2.5-meter range, is considered by some observers to be "nothing more than a Japan Defense Agency mission in disguise."(115) Moreover, the technologies on these ostensibly commercial programs are likely to be adapted for the reconnaissance satellites currently being developed by Mitsubishi Electric Corporation as the lead contractor.(116) India views its remote sensing space programs as a matter of national prestige; Prime Minister A.B. Vajpayee, who presided over India's nuclear tests in May 1998, has praised the scientists at ISRO, saying that satellites are part of "the cardinal principle of self reliance."(117) By offering its satellite imagery on the commercial market, India can gain needed funding to support its space development programs.(118) Israel's expertise in military imaging satellites will increase its competitiveness in the commercial market. Israel expects to sell its satellite products to both government and commercial users.(119)

As the global market is becoming increasingly competitive, the challenge to U.S. industry to compete is greater. At the same time, U.S. Government regulation requires companies to permit the U.S. government access to all records for satellite tasking and to notify the U.S. government of any new foreign customers.(120) In addition, U.S. government regulation prohibits U.S. companies from offering better than two-meter resolution images of Israel on the commercial market.(121) These regulatory restrictions create impediments and uncertainties with consequence.

Slowing growth of the U.S. remote sensing satellite industry not only has economic and market effects, but also affects availability of commercial satellite imaging products for the U.S. Government. The success of U.S. remote sensing satellite companies could potentially benefit the U.S. government by creating a solid base of American suppliers to support the government's requirements for satellite imaging data. For example, the National Imagery and Mapping Agency (NIMA)(122) plans to buy $35 million worth of commercial imagery and ground equipment in fiscal year 2001 for uses ranging from military planning to disaster relief operations.(123) It has noted that the organization would like to purchase more commercial satellite imagery but the existence of a single supplier (at this time) has limited its plans. In addition, in support of the U.S. Government's recent half-meter license authorization, NIMA noted that the use of commercial imagery is important to relieve pressure on heavily tasked U.S. intelligence sources.(124)

An independent Commission established by Congress to review NIMA (NIMA Commission) stated in its December 2000 report that it "endorses the move to allow US companies to move to higher resolution as required by the competition and demanded by the marketplace. It will demonstrate continued technical superiority and signal US government intent to keep US companies in the forefront."(125) The NIMA Commission also explained that "improved resolution clearly allows new information to be extracted from an image. As imagery moves ... to one meter and below, military applications move beyond terrain analysis, through gross targeting, to precision targeting, bomb damage assessment, order-of-battle assessment, to technical intelligence findings."(126)

(Section V.E. below, which discusses the implications of multinational alliances and globalization with respect to communications satellites, is generally applicable to other satellite services, including remote sensing satellites. In addition, Section VII. below, which discusses legal and regulatory issues and the need for interagency coordination involving all four space sectors, has applicability to remote sensing satellite services.)

IV. Location, Navigation and Timing Satellite Services

A. Background

Global Positioning System (GPS) satellites broadcast signals that allow receivers to derive precise timing, location and velocity information. The U.S. GPS consists of three components: the space segment, the control segment and the user segment. The GPS space segment, which the Department of Defense owns and operates, consists of a minimum of 24 satellites (six planes of at least four satellites each) in near-circular semi-synchronous orbits (one orbit every 12 hours) evenly spaced around the earth. Each plane is inclined 55 degrees to the Earth's equator. This configuration allows any GPS user anywhere on the earth to see at least four satellites.(127) The satellites carry very stable atomic clocks that are used to derive the ranging signals.

The Department of Defense also owns and operates the GPS operational control segment, which consists of monitor stations, ground antennae and a master control station. The five monitor stations located around the world track and monitor GPS satellite navigation and timing signals to estimate the orbits and clock behavior. The four ground antennae located around the world upload information to the satellites and monitor satellite state of health. The Master Control Station in Colorado Springs processes data, generates satellite commands and new navigation updates provided to the satellites once or twice daily.

The user segment consists of GPS receivers that are hand carried or installed on aircraft, ground vehicles, or sea-going vessels. The receivers, which are owned by both civilian and military users, detect, decode and process the signals transmitted by the satellites. The receivers convert the signals into position, velocity, and time estimates, allowing the user to determine a location instantaneously with a high degree of accuracy.

The U.S. Government originally developed GPS for military applications with limited provisions for civil access on a subscription basis. The Department of Transportation is the lead agency for all federal civil GPS matters. The Department of State is charged with developing bilateral and multilateral guidelines on the provision of GPS services. Since 1984, however, the U.S. government has allowed free public access to GPS signals, albeit at a downgraded quality.(128) In May 2000, the U.S. government ended the practice of downgrading the quality of signals from its GPS satellites.(129) The ending of "Selective

Availability" allowed users worldwide to obtain location accuracy within less than10 meters.(130) The improved accuracy is expected to increase the use of GPS-related technology in the commercial market.

Over the past three to four years, the location/navigation sector has been growing at an annual rate of about 20-25% and is expected to continue to become a major revenue-producing part of worldwide commercial space industry within the next five years. One estimate is that GPS equipment and services revenue will increase from about $6.1 billion in 1999 to about $16.1 billion in 2005.(131) GPS equipment and services are expected to produce about 10% of the total world space revenue by 2005.(132) The Department of Commerce estimates worldwide annual sales of GPS goods and service of at least $16 billion by 2003, with the United States expected to retain about a third of the global market share.(133)

B. Commercial Applications

The number of commercial applications for location/navigation satellite signals is increasing. The precisely timed signals emitted by the satellites can be used for a multitude of purposes, including the control of automated farm equipment, emergency location services, the timing of signals for the wireless telephone industry, and as the basis for a U.S. national air traffic control system.

1. Navigation Services

Over the near term, the GPS car navigation market is expected to increase in the United States, Europe and Japan. The International Trade Administration projects that the car navigation segment will continue to be the largest revenue-producing GPS segment through 2003, but growth in the segment is expected to slow as the market becomes saturated.(134) GPS signals can be combined with communications satellite assets to provide efficient routing and scheduling information, as well as the real time tracking of high-value or dangerous cargoes. GPS location signals can be used to track and locate most transportation vehicles in the ground, sea, or air.(135) GPS provides life-saving location and navigation information in search and rescue and emergency situations. For example, on December 17, 2000, U.S. Coast Guard helicopters rescued 34 crewmembers from a passenger ship, *Sea Breeze I*, which was sinking about 200 miles east of Cape Charles, Virginia. GPS technology allowed rescuers to identify the location of the ship and enabled the timely and successful rescue of the ship's entire crew.(136)

GPS signals are considered extremely reliable and efficient for aircraft tracking applications. In 2002, the Federal Aviation Administration (FAA) intends to implement an all-GPS location/navigation system throughout the National Airspace System (NAS) as a means to save on operating costs(137) to provide basic navigation capability.(138) Another valuable GPS application is related to emergency services. The Federal Communications Commission (FCC) has mandated that by October 2001, mobile cellular telephones must be capable of providing users' positions within 25 meters in case of an emergency.(139)

GPS technologies are extremely valuable for agriculture purposes, and can help guide farm equipment for planting and other uses,(140) increasing efficiency and reducing per acre costs.(141) GPS signals may be used to measure structural deformities in infrastructure such as bridges and railroad tracks(142) or to measure structural movements of hydroelectric dams or of high-speed rail tracks.

2. Timing Services

The extremely accurate atomic timing clocks in the GPS satellites transmit information to any point in the world, twenty-four hours per day. GPS clocks provide ideal solutions to many of these synchronization requirements.(143) It is becoming less expensive for telecommunications companies to deploy GPS receivers to synchronize their network clocks rather than maintain a separate timing system, which is not likely to be as accurate. These applications are expected to increase as new information technologies are developed and introduced. The range of applications for GPS and its necessity in an increasingly information-technology dominated world are making GPS an indispensable part of the infrastructure of modern global societies. The GPS timing segment grew at a rate of 65% in 1997, compared to the 23% rate in the overall GPS market itself.(144)

The timing mechanism in the GPS system is critically important to a number of other technologies and services. For example, technologies for the electronic switching and transmission of voice, data and video require extremely accurate time synchronization. Broadcast radio and television and wide and local area networks require accurate time transfer.(145) Cellular telephones that operate on a time-based technology also rely on accurate timing. Financial banking and the growing e-commerce industry, require some form of accurate synchronization to certify the time of transactions. Network routers and switches require timing synchronization that GPS signals can provide. Wireless telecommunications data transfer requires an independent timing source so that signals are not lost or dropped because of electronic interference with system clocks of wireless stations.

C. Technological Trends

The two most important technological trends in the GPS industry are the decreases in cost of GPS receivers and the productivity gains from embedded software. Hardware cost decreases have made GPS technology affordable to many more consumers and hardware size reductions have made GPS technology much more convenient. In 1983, when GPS commercial receivers became available, the cost was over $150,000 for equipment that weighed over a hundred pounds. In 1998, GPS receivers were available in handheld versions weighing less than 12 ounces for about $100.(146)

U.S. firms are principal providers of GPS products. Trimble Navigation, Orbital Science, Rockwell, and Motorola produce and package complete GPS user equipment, while Boeing Corporation manufactures GPS satellites. Outside of the United States, the Japanese market has the largest GPS revenues and is expected to increase in proportion to other regional markets in the short term, mostly because of car navigation sales.(147) Japanese companies involved in the manufacture of GPS receivers are Nippon Motorola, Mitsui, Pioneer Electronic, Sharp Sony and Toyota. The Japanese GPS industry tends to receive substantial support from the government and from private Japanese car and railroad manufacturers, which are major users of Japanese GPS equipment.(148)

D. National Security Implications

1. U.S. GPS System

Some of the GPS satellites currently on orbit lack redundancy and there is a small probability that three or more satellite could fail. The Department of Defense is committed to ensuring that adequate satellites are available, in orbit and ready for launch. Should the number of operational satellites fall below desired levels, however, GPS users in some areas could experience reduced accuracy and coverage could be affected that will be launched prior to the cessation of on-orbit satellites."(149)

2. Foreign Navigation and Location Satellite Systems

Foreign country development of navigation and location satellite services raise issues regarding radio frequency spectrum, interference and compatibility issues regarding the GPS system. In addition, the foreign satellite systems may be used for military purposes.

Russia has a navigation and location system called the Global Navigation Satellite System (GLONASS). It is similar to U.S.-based GPS, but is considered to be less reliable by most worldwide users. The European Union has plans for developing a constellation of global positioning satellites called Galileo.(150) A purpose of the project is to provide an alternative system in the event that the region would be denied access to the U.S. GPS system during a regional crisis within Europe.(151) In addition, the European Union expects to receive substantial industrial benefits from implementing a global navigation and positioning system, principally improving the technological competitiveness of European manufacturers.(152) The Galileo system has required negotiations between the United States and the European Union regarding coordination of links between the Galileo constellation and the U.S.-operated GPS system.(153)

The Japanese government also has studied the possibility of developing a navigation and location satellite system of its own. In 1996, Japan's National Space Development Agency (NASDA) submitted a plan to deploy a four-satellite test system in 2002 to support local GPS systems in Japan and the Asian region with the option of building a larger system later. Like the Europeans, Japanese observers have recognized that Japan should develop or at least explore alternatives to the U.S.-controlled GPS signals.

Given these foreign sentiments, it is likely that foreign nations, in addition to Russia, will begin to deploy their own navigation and locations systems within the next decade. Despite the technical considerations and costs of doing so, other countries have concerns about depending on the U.S. government for global positioning requirements. Once these countries deploy navigation and location systems of their own, they and others may derive similar national security, commercial, civil, economic and technological benefits that the U.S. GPS system affords this nation.

(Section V.E. below, which discusses the implications of multinational alliances and globalization with respect to communications satellites, is generally applicable to other satellite services, including location, navigation and timing satellite services. In addition, Section VII. below, which discusses legal and regulatory issues and the need for interagency coordination involving all four space sectors, has applicability to location, navigation and timing satellite services.)

V. Communications Satellite Services

A. Background

The commercial communications satellite sector provides an array of services to millions of users around the globe. Satellite communications services allow businesses to track inventory, a journalist to file a story from abroad, a U.S. Navy sailor to call home from sea, a student in Africa to access the Internet or a U.S. company to beam video programming in South America. Commercial satellite systems also support intelligence, defense and foreign policy missions of the United States and its allies.

Today, the commercial communications satellite segment represents a significant portion of the worldwide space industry. ING Barings estimates that global commercial communications satellite revenues in the year 2000 will total $50.1 billion, nearly double to $95.4 billion by 2005 and reach $121.7 billion in 2009.(154) Although competition from other types of telecommunications services--principally fiber--and regulatory policies affect the commercial communications satellite services segment, analysts forecast that the satellite industry will grow,(155) particularly for broadband and Internet services.(156)

The number of commercial communications satellites is expected to increase. Futron Corporation forecasts that the number of commercial communications geostationary satellites will almost double by 2010, from approximately 200 today to approximately 290 in 2005 and 375 in 2010.(157) Highest growth is expected in data communications, with business data communications accounting for about 60% of the geostationary commercial data communications satellite market.(158)

B. Communications Satellite Technology and Investment Incentives

The technological characteristics of any telecommunications source, as well as the geographic and demographic features of a service area, influence investment incentives and infrastructure deployment. For example, in urban areas in the United States with high-density population, the traditional infrastructure has been wireline networks. Areas with low-density populations, such as rural areas, however, generally have fewer wireline networks because the return on investment is not commercially viable. In some rural or remote areas, satellites provide basic telecommunications services. Satellites also are useful for serving geographic areas that have rough terrain where it is more difficult or expensive to install fiber networks. Where there are no ground-based telecommunication sources available--ships at sea, for example--satellites offer the only alternative.

Industry observers link the technological features of satellites to the industry's growth potential. ING Barings states that "While it is true that a host of terrestrial technologies ... will challenge broadband satellite networks for market share in the broadband sector, satellites are poised to claim a substantial portion of the total broadband market due to a number of advantages they hold over terrestrial competitors."(159)

Satellites have both technical limitations and advantages. For example, because of the far distance of satellites from the Earth, especially geosynchronous satellites, there is a slight delay in communication transmissions. Voice communications are especially affected by this delay. In addition, atmospheric conditions such as rain can affect quality. At the same time, satellite technology is improving. Technological developments permit more economical use. For example, satellites can operate on-orbit for longer periods of time, reducing replacement and launch costs. While Early Bird, the world's first commercial communications satellite, had a four-year consecutive lifespan,(160) a satellite's lifetime now is about 15 years.

Today's new, larger satellites can deliver more tailored and smaller spot beams to serve different types of customers. Differential capacity and longer satellite lifetimes allow for lower costs per digital bit of data than those offered by smaller satellite designs.(161) Multicasting eliminates need for redundant, multiple data streams when many users request identical data. Caching will enable the transmission to and storing of Internet data on local servers, reducing the need to retrieve data directly from the content source, thereby reducing congestion in the U.S. terrestrial backbone, particularly at frequently-accessed Internet sites. In addition, satellites are heavily used to "backhaul" Internet traffic to and from Internet Service Providers (ISPs) located outside the United States.

Very Small Aperture Terminals (VSAT) networks are particularly efficient means of point-to-multipoint distribution. VSAT networks consist of a satellite, a central ("hub") ground antenna about three to six feet in size, and up to thousands of remote smaller ground antenna.(162) VSATs provide two-way voice, data and video communications. They offer fast delivery, flexibility, low cost solutions, user control, low expansion costs, high reliability, predictability and overall network availability at levels up to 99.9%.(163) Financial institutions utilize VSAT networks for credit authorizations and on-line trading services; energy companies use VSATs to monitor pipelines; and shipping companies use VSAT networks to track shipping, provide on-time delivery, and conduct customer business. Wal-Mart, for example, uses a PanAmSat-based VSAT system to connect more than 3,000 of its stores, Sam's Clubs and distribution centers across the United States.(164)

Availability of sufficient satellite capacity also affects the industry's viability. Satellite companies often sell most of the capacity on a satellite prior to launch, leaving little excess capacity. In addition, broadband applications--for which satellites hold great potential--need tremendous amounts of bandwidth. The capacity on terrestrial wireline systems generally far exceeds satellite capacity.(165) Another concern is current delays in the development of new launch vehicles to launch the next generation of satellites, which are heavier due to enhanced capabilities. In addition, companies cite lack of public awareness of satellite technology and other factors as affecting the market. For example, lack of trained satellite service people in the quickly changing field of satellite technology is a another challenge.(166)

Financial, economic and competition factors substantially influence viability. As a result, the commercial communications satellite market has fluctuated. Competition from land-based systems, steep initial costs of designing, constructing and launching satellite systems, particular business plans and regulatory delay have created problems for some types of satellite services.(167) Consequently, some commercial satellite providers have been forced to change their marketing strategies, merge with other companies or file for bankruptcy.

Satellite systems that have experienced difficulty are global mobile low earth orbit (LEO) (nongeosynchronous) systems such as those of Iridium, Globalstar and ICO. These systems each involve large constellations, require high start-up costs and face stiff competition from terrestrial systems. For example, Iridium developed a global constellation of 66 LEO satellites to provide mobile telephone services. Iridium started operating in 1998, filed for bankruptcy in 1999 and became a new company, Iridium Satellite LLC in late 2000.(168) Globalstar, which is a consortium of international telecommunications companies led by U.S.-based Loral, provides global wireless digital telephone, data transmissions, paging, facsimile and position location services to mobile users worldwide, has encountered similar problems, stemming in part from a slow start-up in service. ICO, which originally planned a voice satellite service, and later filed for bankruptcy, has emerged as New ICO and entered an arrangement with Teledesic.(169)

In sum, some commercial communications satellite services have faced challenges. Others have been successful. Looking ahead, financial analysts see certain communications satellite services--television, radio and broadband, for example--as having long-term viability. In any event, as detailed in the following section, communications satellite services have many applications in American life and commerce.

C. Principal Applications

Commercial communications satellite systems provide a variety of services in the United States and around the globe. These include for example, telephone, electronic newsgathering, data, video, television, radio and Internet services to both fixed (stationary) and mobile users.

1. Voice, Messaging and Tracking Services

One of the first communications services by satellite was basic voice telephone service. Beginning in the 1960s and continuing today, COMSAT (now Lockheed Martin), provides international satellite telephony through the INTELSAT system using geosynchronous satellites. Thereafter, the former American Mobile Satellite Company (now Motient)(170) provided domestic voice services to fixed and mobile users through its own geosynchronous satellites. In recent years, other companies have developed new nongeosynchrounous satellite systems to deliver voice and other communications services. As described above, the satellite telephony segment has not proved to be as strong as other commercial satellite service segments.

Geosynchronous and nongeosynchronous satellites systems also provide data services. For example, LEO satellite systems operating in lower bandwidths provide data messaging services such as paging, e-mail and remote meter reading. These systems enable tracking of government assets, rail cars, trailers, locomotives, heavy equipment an containers, monitoring of environmental projects, remote electric utility meters, oil an gas storage tanks, wells and pipelines and messaging services for consumers, businesses and governments. Like LEO telephone satellite systems, LEO data systems generally have faced financial difficulties.

2. Broadband and Internet Services

The fastest growing commercial communications application for satellites is the provision of broadband services. Generally, broadband services are robust, content-oriented communications that use large amounts of capacity and move at fast speeds. Broadband applications include high-speed data over private corporate-based VSAT networks, business television services by satellite to corporations for distance training, teleconferencing, special events and Internet access. Wall Street analysts consider satellites to be well-positioned to provide broadband services.(171) Satellites avoid the congestion of Internet networks and efficiently address the asymmetrical flow of Internet traffic.(172) Merrill Lynch forecasts that future broadband opportunities "should provide a significant source of growth in the satellite sector over the next decade."(173) ING Barings projects that broadband satellite services will become a $20 billion industry by 2009.(174) C.E. Unterberg, Towbin, however, cautions that growth in the broadband satellite sector could be constrained by high space segment costs.(175)

Several satellite companies are providing either connectivity to the Internet backbone or Internet service directly, avoiding the terrestrial Internet network. For example, PanAmSat,(176) has provided international Internet services since the early 1990s, initially in collaboration with the National Science Foundation to connect Mongolia to the U.S. backbone.(177) Loral provides access to U.S.-based content to more than 130 Internet Service Providers in over 32 countries.(178) Africa Online(179) offers Internet access services to residential consumers, home offices and businesses.(180)

The potential for growth in broadband applications has encouraged development of new satellite systems that would provide broadband access directly to end users. These include the Hughes' Spaceway system, Lockheed Martin's Astrolink system, the Teledesic system and the Skybridge system. For example, ICO-Teledesic Global Limited, plans to be a global provider of wireless Internet-in the-SkyTM satellite communications service, including Internet Protocol-based mobile and fixed broadband services.(181) New ICO plans to offer satellite Internet service worldwide in 2003 and Teledesic intends to deliver broadband data and value-added services over a global network in late 2004.

3. Satellite Television Services

One of the most successful uses of satellites to date is the provision of television service by satellite. Called the "Direct Broadcast Satellite service (DBS)" or "Direct to Home" (DTH),(182) like cable television, this satellite service provides hundreds of channels of television programming directly to homes and businesses. DBS providers in the United States include EchoStar Communications Company (EchoStar), Hughes Network Systems (DirecTV) and Pegasus, which serves rural and unserved areas.(183)

DBS, which began in the United States in 1994, is a success. In 2000, there were approximately 15.94 million DBS subscribers in the United States, representing approximately 18.16% of the U.S. home subscription television market.(184) DBS provides direct competition to cable and other multichannel services. DBS providers have begun to offer interactive television. As of year-end 2000, there were approximately five million interactive-capable satellite households in the United States.(185) ING Barings predicts that U.S. DBS revenues in 2000 will be $7.9 billion and in 2009, triple to $23.1 billion. (186)

Although DBS is expected to continue to grow in number of subscribers and amount of revenues, it is not expected to exceed cable's share of the U.S. home subscription television market. For example, in 2008, though the number of U.S. subscribers will rise to 28.75 million, this figure will represent 27.4% of the subscription television market.(187) On the other hand, as DBS companies expand their offerings to include broadband applications, they are expected to "add a significant advantage in the competition for customers with digital cable."(188) "We believe that broadband data transmission applications and new interactive video services should continue to drive the [DBS] sector."(189) Some of these advantages are diminishing, however, as cable operators offer digital services that will match DBS channels and signal quality. Cable systems, are increasingly providing high-speed Internet access.

Satellite television services are widespread outside the United States where cable systems are not as prevalent as they are in the United States. Operators include both U.S. and non-U.S. entities, such as European based- SES Astra and EUTELSAT, a European treaty-based satellite organization, which delivers satellite television to millions of homes in Europe, Africa and Asia.(190) ING Barings estimates that international U.S. DBS revenues will more than double from $14.6 billion in 2000 to $32.8 billion in 2009. (191)

4. Satellite Radio Services

Satellites also provide radio services. This service is called the "Digital Audio Radio Satellite Service" (DARS). In 2001, for the first time in the United States, two U.S. DARS licensees, XM Satellite Radio and Sirius Satellite, are expected to deliver radio channels directly to vehicles and homes.(192) Financial analysts are positive about DARS. According to C.E. Unterberg Towbin, DARS "promises to revolutionize the radio industry, much the same way cable and satellite television revolutionized the television industry." (193) DARS is described as a "quintessential" satellite business because it can serve a large geographic region with hundreds of millions of consumers and its offerings of ethnic programming, world and business news, fewer commercials and digital quality "will drive consumers to satellite radio."(194)

DARS already is available in other countries. For example, WorldSpace provides DARS service in Africa and Asia and reportedly is forming an alliance with Alcatel to seek partners in a consortium to provide up to 100 channels of radio, plus short messaging services throughout Europe.(195)

5. Service to Rural and Unserved Areas

Traditionally, it has not been cost effective to deploy fiber systems in remote, low density areas. As a result, those areas have had inadequate telecommunications services. Largely through use of satellites and other wireless technologies, this situation is changing. Wall Street views rural and unserved regions as growth areas for the satellite industry. Governments and companies worldwide are undertaking efforts to increase telecommunications services to these areas. For example, various U.S. Government agencies and states have launched initiatives to encourage deployment of telecommunications services to unserved areas, including Native American lands.(196) "We remain committed to encouraging the expeditious delivery of telecommunications services, via satellite services, to unserved communities. The comments in this proceeding support our belief that satellites are an excellent technology for delivering these services."(197) In Somalia, where the state telephone system was destroyed by war, new satellite telephone booths enable residents to call anywhere in the world.(198) As a result of these measures, large populations of people that just a short time ago did not have even basic telecommunications capabilities readily available now have access to communications technology.

6. Disaster Relief and Emergency

Services Satellites are instrumental in delivering disaster relief and emergency services.(199) Satellites are particularly advantageous for emergency purposes in rural and remote areas that lack other communications capabilities.(200) For example, in Native American areas in the United States, satellite systems have been used to provide police dispatch and other emergency services to tribal residents. In addition, in emergency and distress situations, an individual can use a satellite telephone, like other phones, to call someone for assistance.(201)

7. Enabling Services

Commercial satellites enable various businesses and technologies to provide services.(202) As described above, satellites support some components of the U.S. critical infrastructures.(203) Many traditional over-the-air television and radio broadcasters, including the major networks, deliver programming to affiliates in the United States in part by satellite.(204) Satellites also deliver programming to cable television company facilities, which those companies then transmit via cable lines to their subscribers. As a result, consumers worldwide are able to see and hear in present time, up-to-the-minute news, sports and entertainment programming on a range of subjects and interests. Estimates are that approximately 30-35% of transponder capacity on commercial geosynchronous satellites is used to relay broadcast and cable television programming.(205) In addition, satellites are part of some terrestrial wireless networks. For example, they transmit information and communications in terrestrial wireless paging services.(206)

Commercial satellite systems provide protection services for communications networks. Massachusetts-based Wang Recovery Services uses a GE American Communications (GE Americom) satellite to provide telephone backup solutions in situations in which a company loses service because of the catastrophic failure of a telephone company's local central office or corporation's own network. Wang reportedly is working with GE Americom to offer its service in Europe.(207) In addition, Wang is now joining with California-based Esat Inc. to provide Esat's Internet and network continuity service via satellite. Esat also can provide a redundant satellite-powered virtual private network to substitute for failed systems. Rotterdam-based Satellite Safe Ltd. serves corporate clients in Europe and South Africa by detecting viruses that can cause significant damage to corporate networks in Europe and South Africa and distributes anti-virus software over satellite.(208) "The only way to deliver this service when the Internet is blocked is from the air.'"(209)

(Section VII. below discusses legal and regulatory issues and the need for interagency coordination involving all four space sectors, which includes commercial communications satellite services.)

D. Business and Regulatory Trends

1. Privatization and Competition

It is an historical time in the global telecommunications marketplace. In the last five years, the market has become more competitive. "The telecommunications and information revolution is bringing dramatic growth and change to the nation's economic, social and political life." (210) Governments are recognizing the advantages of competition in the telecommunications sector in general, and satellites in particular, for their economies, businesses and people. Government-owned telecommunications monopolies have begun to privatize and other nations are opening their markets to foreign entry. In addition, intergovernmental satellite organizations, which as explained below, have enjoyed special legal status for decades, are privatizing in order to respond to competitive pressures in the satellite marketplace.(211)

Privatization of Multilateral Satellite Treaty Organizations

From the 1970s until a few years ago, the majority of satellites providing nonmilitary applications were owned and operated by multilateral treaty organizations. The three largest of these organizations are: Washington, D.C.-based INTELSAT, London-based INMARSAT and Paris-based EUTELSAT. Each of these satellite organizations was formed pursuant to a multilateral treaty.(212) They have been comprised of government entities representing the nations that are party to the treaty and commercial companies that operate and use the services of the respective satellite systems.(213) By treaty, these organizations have held special legal status and enjoyed certain privileges and immunities. For example, INTELSAT is immune from taxes and from suits in national courts, unless it waives its immunity. The intergovernmental satellite organizations are privatizing. INMARSAT, a global mobile satellite service provider, privatized last year and is expected to conduct an initial public offering in 2001.(214) EUTELSAT, the European, treaty-based satellite organization also will privatize by mid-2001.(215)

INTELSAT will privatize in July 2001.(216) As a U.S. company, INTELSAT will be subject to U.S. competition laws and domestic regulations. (INTELSAT has never before been under the jurisdiction of any nation in the world.) As such, INTELSAT will operate as a private entity subject to the global competitive satellite marketplace and will be positioned to offer competitive satellite services to the benefit of U.S. consumers, including the U.S. Government. Location of privatized INTELSAT in the United States will be beneficial to the United States. Its assets include nearly 20 satellites and accompanying orbital locations estimated to be worth billions of dollars. With INTELSAT as a U.S. company, it will be easier for other U.S. companies to coordinate their satellite systems than if INTELSAT were located in a foreign jurisdiction. In addition, as the largest, longest-lasting, multinational communications satellite entity in the world, and a provider of satellite services for commercial and U.S. Government use, INTELSAT and its workforce offer extraordinary technical, international and business expertise. Finally, when INTELSAT is privatized, the United States will host the two largest geosynchronous satellite companies in the world--INTELSAT and PanAmSat.

The 1997 WTO Basic Telecommunications Services Agreement

The principal historic step toward a more competitive commercial global satellite market was the signing of the1997 World Trade Organization (WTO) Fourth Protocol to the General Agreement on Trade in Services (WTO Agreement).(217) Sixty-nine WTO members originally signed the WTO Agreement representing over 90% of the world's basic telecommunications revenues.(218) The United States committed, among other things, to provide market access for satellite services.(219) The WTO Agreement imposes competitive safeguards on most signatories, including the United States, such as impartial regulatory treatment and nondiscriminatory allocation and use of scarce resources.

The Federal Communications Commission implemented the WTO Agreement in 1997, establishing open entry standards for WTO members consistent with the U.S. schedule of commitments.(220) The WTO Agreement contains an exception for measures required to protect national security.(221) In implementing the WTO Agreement, the Federal Communications Commission adopted rules according deference to the expertise of the Executive Branch on licensing matters involving national security, foreign policy, law enforcement and trade.(222) In addition, the U.S. WTO commitments contain foreign ownership limitations consistent with the proscriptions in the Communications Act of 1934.

In the three years since its implementation, the WTO Agreement has made a difference. "Clearly, the WTO has set an important benchmark for opening markets to satellite services around the world. Many countries--particularly in Latin America and increasingly in Europe, Africa, and Asia as well--have liberalized their regulations."(223) The WTO Agreement has provided new business opportunities and increased opportunities for competition in the provision of telecommunications services, including satellite services, in the United States and abroad. New WTO trade talks are underway. There are efforts to increase the number of signatory countries and to improve and clarify existing commitments.

Effects and Benefits

Privatization, liberalization and competition are having a substantial effect on the commercial communications satellite industry. Progressive regulatory actions and market expansion are producing tremendous benefits for consumers worldwide. Users are receiving the benefits of lower prices, greater service choices and innovative technology.(224) As a result of liberalization, satellite companies are seizing the opportunity to provide services in previously-closed markets and to expand in existing ones. They are forming new multinational alliances to gain access to capital, to develop better products, to obtain requisite licenses in foreign countries and to market services in other nations.(225) This new competitive dynamic is driving the commercial satellite communications industry in two related directions: toward multinational alliances and globalization. Examples of this trend, by geographic region, follow below.

2. Business Trends by Region

North America

Foreign companies view the United States as favorable for satellite services because of its accessible market, transparent licensing and legal system, access to capital, and large, relatively affluent consumer base. A satellite does not have to be licensed by the United States in order to provide service within the United States. Since the WTO Agreement liberalized the U.S. market, several foreign companies have sought to provide satellite services in the United States. In 1999, Canadian-based TMI Communications and Company, L.P. and Netherlands-based New Skies Satellites, N.V. (the INTELSAT spin-off), received authorization to operate in the United States.(226) In 2000, the Federal Communications Commission authorized foreign satellites from Argentina, Brazil, Canada, Japan, Mexico, the Phillipines (Indonesian registry) and EUTELSAT to serve the United States.(227) North America is expected to be the largest market for broadband services.(228)

Telesat Canada owns and operates several communications satellites. In 2000, the company launched its newest generation satellite, the Boeing-built Anik F1, which will serve North and South America. In late 2002, Telesat Canada plans to provide Ka-band multimedia satellite services in North America.(229) Telesat Canada also owns and operates satellite serving the direct-to-home broadcast (satellite television) market.(230)

Latin and South America

The market for satellite telephone, Internet and television services has become increasingly competitive in South America. Data services have dominated the growth of applications in the region, as nations upgrade their infrastructures to meet the strong and sustained growth of the Internet. One projection is that the Internet will grow in Latin and South America at an annual rate of 32% over the next five years, representing a $5 billion market by 2005.(231) As described below, the region is developing its own satellites, while at the same time a number of U.S. and other companies have started satellite ventures in Latin and South America.

The rapid development of satellite services in Brazil is an example of new satellite markets. Embratel, Brazil's primary communications provider and domestic satellite operator, now is owned partially by U.S.-based MCI Worldcom and SESAstra.(232) With a fleet of four satellites, Embratel is providing various satellite communications services, including backbone connections to Internet service providers(233) and is exploring more broadband opportunities.(234) In November 2000, Globalstar Do Brasil announced that it was equipping buses in Brazil with mobile satellite telephones.(235)

Following its 1997 privatization, Mexico's Satmex has emerged as one of the region's largest satellite service providers. Satmex is a joint venture between Mexico-owned Principia and U.S.-based Loral Space & Communications.(236) It has sharply expanded its customer base by entering agreements with a number of Internet-related companies such as Tachyon, Hughes Network Systems and American Multiplexer. Satmex plans to obtain additional capacity through the Loral Global Alliance(237) and to launch two additional satellites after 2003.(238) Hispasat, Spain's satellite operator, has been authorized to serve Brazil and expects to increase its presence in South America.

Nahuelsat S.A., Argentina's largest satellite service provider, is expanding throughout South America, including the Andean nations and Mexico.(239) General Electric Capital Corporation (GE) owns 28% of Nahuelsat, and may seek to acquire a larger share of the company. Intelsat has a strong presence in South America.

Venezuela, Ecuador, Peru, Bolivia, and Colombia are members of Andesat (the Andean Countries Satellite Project), a consortium designed to provide Andean nations with an independent satellite capability. Andesat and Alcatel Space are partners in a joint venture known as BolivarSat, which is licensed to operate and plans to launch its first communications satellite, Simon Bolivar, sometime in mid-2002.(240) Andesat intends to provide television, telephone, trunking, beeper, radio, telephony and broadband Internet service to consumers.(241)

In 2000, PanAmSat was licensed to offer Internet Protocol and telephony services in Peru(242) and launched two new satellites to serve Latin America. Loral Cyberstar provides data satellite services in the region and is considering providing distance learning and business television satellite services in the region as well. In July 2000, ORBCOMM, a U.S. low-earth orbit messaging company, received a license in Colombia and intends to serve Colombia's transportation, oil and gas, utility and other industries.(243) Eutelsat do Brasil plans to expand service in South America in 2001, providing video and Internet services.(244)

Europe and the Middle East

Internet and DTH expansion is expected to drive growth of satellite services across Europe. Approximately 97 satellites and 1,100 transponders with regional and/or international coverage were serving Europe in 1999.(245) Industry analysts predict that the number of transponders dedicated to providing Internet service will need to increase from 27 in 1999 to 343 in 2009 to support backbone trunking and Internet access.(246) European operators could face serious capacity shortages without a substantial increase in satellites on-orbit.(247)

EUTELSAT is experiencing strong growth in Europe and abroad. EUTELSAT's fleet contains 17 satellites and nearly 300 transponders that cover all of Europe and Africa, as well as parts of Asia and North America.(248) With its fleet near capacity, the organization is procuring additional satellites.(249) EUTELSAT is venturing into educational services through a partnership with the CNIT (Italy's inter-university consortium for telecommunications) to broadcast distance learning courses for postdoctoral students.(250)

SES Astra is expanding its presence in Europe and Asia, two growing markets. In July 2000, SES Astra purchased a 50% stake in the Nordic Satellite Co. of Scandinavia. This move gives SES Astra an expanded geographic market in the Nordic region, and will be critical in SES Astra's efforts to spread Astra Net broadband services across Europe. Although SES Astra has expressed considerable interest in partnering with a North American company in order to gain a foothold in the American and Canadian satellite service market, it has not yet done so. SES Astra operates eleven satellites through which it transmits more than 950 television and radio channels, multimedia and Internet services to 78 million homes.(251) Four more satellites are planned for launch in 2001.

Europe*Star, a joint venture between Alcatel Spacecom and Loral Space and Communications, entered the European market with the launch of its first satellite in October 2000. Europe*Star is forming partnerships with other companies to deliver end-to-end solutions to ISPs.(252) The partners will provide gateway connections, uplinking, fiber and connection to the Internet and production facilities. Europe*Star is part of the Loral Global alliance and has an agreement with Loral Skynet under which the companies can access each other's capacities.(253) Inmarsat Venture is targeting business users to expand into fixed-satellite services in Europe. It has acquired Scotland's EAE Ltd., a VSAT services company that specializes in providing 2 Mbps connections to the oil, gas and maritime industries from both fixed and mobile terminals.(254)

Monaco-based Eurasiasat, a joint venture of Turk Telecom and Alcatel, is expected to launch its first satellite in early 2001 to serve broadcasters in Turkey, Europe and Central Asia.(255) A new company, Eurasianet, has been created within Eurasiasat to provide end-to-end connectivity with ISPs. This service uses Turksat and INTELSAT capacity. Saudi Globalstar has introduced full commercial service in Saudi Arabia.(256)

Africa

African nations have undertaken substantive measures over the last decade to both create and upgrade telecommunications networks.(257) There is a focus on providing low-cost services, particularly telephony, to rural regions through the use of satellites. A number of African nations have privatized and deregulated their communication industries to open them up to competition, foreign investment and new technology.(258)

The Regional African Satellite Communications Organization (RASCOM), a consortium of 46 African nations, is planning to construct a dedicated satellite system for Africa. Rascom's first satellite is scheduled to be launched in 2002. France's Alcatel has provided funding and engineering expertise for the project.(259) RASCOM intends to launch two geosynchronous satellites to provide telephony, data and video services across Africa and encourage the exchange of television and radio programming among African nations.(260) In addition, Egypt has entered the African service market in recent years providing television satellite services across Northern Africa.(261)

African countries rely on the INTELSAT system for traditional voice, data and video services. In addition, INTELSAT has promoted the growth of Internet services throughout Africa. PanAmSat also has a presence in Africa, providing comprehensive television coverage to the entire African continent(262) and Telesat Canada is entering the market.(263)

Asia-Pacific

Like other regions of the world, the Asia Pacific region is now experiencing satellite growth from both local ventures and outside investment. After a decline in the late 1990s, the market for geosynchronous satellites in the Asia Pacific region is beginning to grow.(264) More than 25 satellites are under construction to serve the region, most of which will provide data and Internet services. As a result of the growth of the Internet in Asia, there is increased demand for Ku-band transponders. Some analysts contend that as the economy improves in Asia, nations will seek to upgrade and expand their bandwidth, digital traffic and packet switching capabilities.(265) Pacific Century Cyberworks, based in Hong Kong, plans to introduce a satellite platform to deliver Internet services to cable head ends. In turn, cable operators would provide Internet services to their own cable subscribers.(266) Industry analysts expect that the growth of DTH and cable television services throughout Asia in the next decade will require increased availability and deployment of geosynchronous satellites. Analysts predict that the DTH and cable market could grow from 84 million users in 1997 to an estimated 237 million users by 2007.(267)

Two geosynchronous systems--Thuraya Satellite Communications Company (Thuraya) and AceS--plan to provide regional telephone service in the Middle East, Central Africa and Europe.(268) Using Boeing-built satellites, in 2001, Thuraya will offer satellite-based mobile services to nearly one-third of the globe, including 99 countries in Europe, the Middle East, North and Central Africa, the Indian subcontinent and Central Asia.(269) The Thuraya system will employ both satellite pay phones and dual mode handsets integrating satellite, terrestrial cellular and location determination (GPS) capabilities in a single handset offering voice, data, fax and short messaging services.(270) In Japan, NTT acquired a 20% stake in Japan satellite systems and consolidated two of its NSTAR satellites into the JSAT fleet.

Companies outside the Asia Pacific region such as Lockheed Martin Global Telecommunications, the Loral Global Alliance, Luxembourg's Societe Europeenne des Satellites (SES Astra) and British Telecom are investing in the Asia-Pacific satellite market and forming new multinational alliances. In Indonesia, for example, Lockheed Martin Global Telecommunications acquired a 30% stake in Asia-Cellular satellite through Pasifik Satelit Nusantara and its regional partners.(271) In 1999, British Telecom acquired a 33% stake in Malaysia's Binariang system, which operates the nation's Malaysia East Asia Satellite (Measat) and SES Astra acquired a 34% stake in Asiasat from Hutchinson Wampoa.(272) SES Astra intends to construct a gateway in Cyprus, which will allow European broadcasters and multimedia companies to distribute services to Asia, Australasia and the Middle East.(273) Europe*Star plans to enter the South

Asian market with its 30 Ku-band transponder satellite.(274) The company has stated that it will use two collocated Ku-band satellites to "interconnect" Europe with South Africa, the Middle East, Indian Subcontinent and Southeast Asia.(275)

E. National Security Implications of Globalization

As the prior section illustrates, there is a tremendous increase in multinational alliances and globalization--across the entire commercial space sector, especially in the communications satellite segment. The rise in multinational alliances and globalization presents both new challenges and opportunities for U.S. national security.

1. Challenges

U.S. companies are forming alliances with foreign companies, entering foreign markets and investing U.S. dollars and resources overseas. At the same time, foreign companies are forming partnerships with U.S. businesses in this country, entering the U.S. satellite market and investing foreign dollars and resources in the United States. As a result of these trends, companies are becoming more global. One company may have multiple owners around the globe and one product may have multiple producers.

That companies of one nation are gaining greater access to the business strategies, systems, products and employees of companies from other nations is not necessarily of concern. Particular alliances or circumstances, however, could create national security considerations. Any such potential concerns would depend on various factors such as the nations, entities, policies and technologies involved. In these situations, the U.S. Government should balance national security and commercial space considerations, including enhancing U.S. competitiveness.

Another consideration is the pending privatization of the multilateral satellite organizations. Those entities hold a tremendous amount of valuable assets--numerous satellites and accompanying orbital locations. Upon privatization, those assets will migrate to the commercial satellite sector and inure to the benefit of the respective country of incorporation of each privatized entity. Furthermore, the privatized entities will have extensive multinational compositions, initially in the form of shareholders and continuously in the form of employees. Based on their historical operations, these entities enjoy longstanding relationships with people in regional and local satellite markets across the globe. The new privatized entities will have the opportunity to leverage those relationships, which depending on the circumstances, could give rise to competition or national security considerations.

As foreign commercial communications satellite companies have sought entry to the U.S. market, the Executive Branch has raised national security, law enforcement and public safety concerns regarding applications that have involved foreign ownership or foreign telecommunications facilities.(276) Some of these applications include U.S. companies in various partnerships with foreign applicants. The specific Executive Branch agencies raising concerns--the Department of Justice and the Federal Bureau of Investigation, as well as the Department of Defense in some cases--have addressed their concerns through written agreements with the applicants. Where foreign facilities are involved, these agreements require construction of a gateway in the United States to enable law enforcement to conduct wiretaps. They also limit foreign access to certain information, impose citizenship requirements, require disclosure of personal data regarding personnel occupying certain sensitive network positions and establish reporting requirements.

Consistent with its *DISCO II* decision implementing the WTO Agreement, the Federal Communications Commission accords deference to the expertise of Executive Branch agencies in identifying and interpreting national security and law enforcement matters, making compliance with these agreements a condition of licensing. In its assessment of the implications of foreign ownership of critical U.S. telecommunications facilities on national security and emergency preparedness services, in May 2000, the Legislative and Regulatory Working Group of the President's National Security Telecommunications Advisory Committee found that the "current regulatory structure effectively accommodated increasing levels of foreign ownership of United States telecommunications facilities, while allowing the Federal Government to retain authority to prevent any such foreign ownership that might compromise national security interests."(277)

In some cases, the amount of time involved in reaching these agreements has caused substantial licensing delays.(278) In the fast-paced, competitive global satellite marketplace, such delays can be costly. As delineated below, these licensing matters call for a more effective, coordinated interagency process to simultaneously: safeguard U.S. national security, comply with U.S. treaty obligations and further competition in the commercial satellite market.

Finally, greater globalization, instant access to and transmission of information as well as the ability to communicate virtually anywhere anytime, may alter people's sense of national boundaries and allegiances. This shift could give rise to new risks and threats, as well as opportunities, as discussed below.

2. Opportunities

Multinational alliances and globalization provide opportunities to enhance U.S. national security. U.S. commercial ventures with foreign entities facilitate U.S. access to foreign funding, business systems, space expertise, technology and intellectual capital. As the Booz, Allen & Hamilton, *2000 Defense Industry Viewpoint* recognizes, "In order to have true competition, government customers will need to look to global competitors, and these relationships will need to extend beyond teaming to a more complete and permanent set of strategic alliances."(279) It identifies these advantages of strategic alliances: (1) strategic alliances provide capabilities to quickly expand service offerings and markets in ways not possible under time and resource constraints; (2) alliances earn a rate of return 50% higher than base businesses; "returns more than double as firms gain experience in alliances;" and (3) alliances are a powerful alternative to acquiring other companies because they "avoid costly accumulation of debt and buildup of balance sheet goodwill." (280)

In these respects, international commercial alliances can serve to strengthen the competitive position of the U.S. commercial satellite sector, providing economic benefits in the United States and furthering a core goal of the *1999 National Security Strategy*: to "bolster America's economic prosperity."(281) U.S. experiences with foreign entities in foreign markets could be beneficial in obtaining the requisite approvals to operate U.S. Government satellite systems in other countries, as well as for resolving satellite spectrum and coordination issues. The lessons of Desert Storm demonstrate that the ability--or inability--to work effectively with other nations to achieve mutual objectives is critical to success. As the *1999 National Security Strategy* states: "Many of our security objectives are best achieved--or can only be achieved--by leveraging our influence and capabilities through international organizations [and] our alliances."(282)

In addition, multinational alliances provide opportunities for the United States to promote international cooperation and build support for U.S. positions with other countries. For example, they can help the United States build consensus on important space-related issues in bilateral or multilateral such as the United Nations, the International Telecommunication Union and the World Trade Organization. Working with emerging space-faring nations is particularly important because of their growing presence in the marketplace and participation in international organizations.(283) These alliances also serve as a bridge to future collaborative efforts between U.S. national security forces and U.S. allies. For example, civil multinational alliances like the International Space Station and the international search and rescue satellite consortium, Cospas-Sarsat, involve multiple countries partnering to use space for common public global purposes.(284) Finally, developing government, business and professional relationships with people in other countries provides opportunities for the United States to further the principles of competition, economic stability and democracy upon which U.S. national security relies.

VI. Weather Satellite Services

A. Background

Like the U.S. GPS satellites, U.S. weather satellites are owned and operated by the U.S. Government as a public service. Specifically, the Department of Commerce National Oceanic and Atmospheric Administration (NOAA) operates two types of weather satellites: the GOES (Geostationary Operational Environmental Satellites) and the POES (Polar Operational Environmental Satellites).

Each of the GOES satellites is able to view a given section of the earth on a constant basis, monitoring atmospheric conditions that trigger severe weather conditions such as tornadoes, flash floods, hailstorms and hurricanes.(285) GOES-8 and GOES-10 are the two most recent geosynchronous weather satellites, launched on April 13, 1994 and April 25, 1997, respectively. The POES satellites, also known as the Advanced Television Infrared Observation Satellite (TIROS-N), are set in sun-synchronous orbits. This allows them to pass over the equator at the same time each day. Operating as a pair, the POES provide data that is no more than six hours old for any region of the world. Data from these satellites is primarily used for longer-range forecasts that do not require 24-hour surveillance capability.(286)

The U.S. Government intends to merge its civilian and military weather satellite programs into the U.S. National Polar-Orbiting Operational Environmental Satellite System (NPOESS). Lockheed Martin and TRW are leading the two teams that will develop and manufacture the next generation satellites. The award of the NPOESS program is expected in 2002 with an anticipated launch date of 2008.(287)

As in both the remote sensing satellite sectors and the location/navigation sectors, the role of government in the control of satellite assets is central to the development of commercial industry. In the United States, civil weather satellites are operated by the National Weather Service (NWS),(288) which provides satellite data as an unrestricted public good.

Commercial weather services represent a niche market. Most of the commercial weather satellite service-related businesses in the United States are value-added providers that process raw weather information from the National Weather Service, then analyze the data to produce custom forecasts. These forecasts are then supplied to consumers such as agribusiness, retail businesses, the news and entertainment industry, local governments and many other customers whose lives or businesses may be affected by changes in the weather. Commercial weather industry analysts estimate that annual revenues in 2000 total about $430 million in the United States, $300 million in Japan and $170 million in Europe.(289) Comparisons to past estimates suggest that revenues in the U.S. commercial industry have been increasing over the past few years. In 1996, for example, Weiss and Backlund's estimate of revenues placed annual sales in the U.S. private weather services industry at $200-250 million.(290)

Based on the $400 million plus revenues generated by the weather service industry in the United States, there is a substantial market for value-added weather products. Moreover, the spread of information technologies such as mobile telephones and Internet services suggests that weather-related content could be packaged with other services intended for the end-user. It is even likely that a "space weather" industry could emerge. Companies that sell and support satellite constellations and/or the technologies that in turn support such space-based assets will require forecasts of extraterrestrial radiation or other phenomena that could affect their operations.(291)

B. Principal Applications

The impact of weather satellites on our daily lives tends to go unnoticed. There are numerous commercial applications for weather satellite information, however, most support forecasts for specialized users. The various applications of weather-related products support a diverse group of customers.

One group of end-users is the large agribusiness industry in the United States. The agribusiness industry relies on accurate weather forecasts for making decisions about the best time to fertilize, apply pesticides, plant, or harvest their crops. Companies such as AccuWeather Inc. package forecasts of weather patterns into specialized reports for their customers.(292)

Another group of frequent users is the retail industry. For example, in the 1980s, Sears, Roebuck & Company typically employed a forecasting group to help it determine the potential for sales of seasonal items such as air conditioners, heaters, snow tires, and umbrellas.(293) By contrast, today, Sears purchases finished weather forecasting products directly from companies such as Strategic Weather Services, which purportedly combines raw weather satellite data with its own "secret formula" to predict Sears' seasonal sales.(294)

The news and entertainment industry also represents a large consumer market for processed satellite weather data. For example, reportedly, at one time the major television networks expressed interests in acquiring the most advanced weather satellites on the market.(295) Because audience share also attracts advertisement dollars, the news and entertainment industry has become an interested consumer of high-tech satellite weather products.

There are other profitable applications of weather satellite information. For example, local governments purchase forecasts from value-added weather service providers. In the aftermath of a blizzard in 1983, New York City government officials credited CompuWeather with predicting the storm, and thereby helping the city to have snowplows and road treatment equipment readily available.(296) In addition, large oil companies have paid $20,000 a month for forecasts of weather and ocean conditions near their offshore drilling platforms.(297) Railroads, ski resorts, airports and any number of other such businesses that are affected by the weather also are likely to purchase value-added services from private sector weather-forecasting companies.

C. Foreign Weather Satellite Programs

Many of the world's space-faring nations cooperate in providing and disseminating weather data to other nations. The principal foreign countries and international regions involved in maintaining weather satellites and their data are Europe, Japan, Russia, China and India.

The European countries operate their Meteosat geosynchronous weather satellites through Eumetsat, a consortium of 16 countries. The Meteosat satellites have similar sensors as the U.S. GOES series of satellites and provide weather observation data for the European continent. A follow-on program, the Meteosat Second Generation (MSG), includes three satellites with enhanced capabilities, including a multi-spectral imager that will acquire full-disc images of the earth at 15-minute intervals and improved geometrical resolution capabilities.(298)

Japan, Russia and China also have their own weather satellites. Japan's latest Geosynchronous Meteorological Satellite, GMS-5, was launched in 1995. Russia has several satellite systems for geological and environmental remote sensing, but its main space-based weather system consists of a single Geosynchronous Operational Meteorological Satellite (GOMS) (launched in 1994). In 1997, China launched its first geosynchronous satellite, the Fengyun-2A (FY-2A). It stopped operating in 1999(299) and in 2000, China successfully launched a second Fengyun satellite, FY-2B.(300)

The Indian weather satellite program differs from those in other countries in that it combines television broadcasting, communications and meteorology.(301) The Indian Space Research Organization (ISRO) operates this satellite program, which is called the INSAT program. The INSAT program began in the early 1980s, with the launch of INSAT-1A. ISRO currently operates a second generation of weather satellites, the INSAT-2 series, which commenced in 1992.(302)

D. Public Good Versus Commercial Product

Most nations acknowledge that weather satellite data should be treated at least partially as a public good and that sharing data among nations is desirable. Even the U.S. weather satellite system, which provides the world's most premier weather satellite capabilities, requires data from other nations to make its models more accurate. Until recently, almost every nation exchanged such data freely within the World Meteorological Organization (WMO).

The view that governments should provide free access to satellite weather data has been called into question within the European Union. Several European governments contend that users should pay a fee for access to certain types of information. In 1995, the National Meteorological Services of Western Europe joined together to form a European Economic Interest Grouping called ECOMET, in part to commercialize the European weather information services.(303) ECOMET created a government commercial enterprise, allowing the members of ECOMET to charge user fees for services that they previously had provided without charge or restrictions. This development resulted in WMO Resolution 40, which created two classes of data: "essential" data on which no restriction could be placed, and "additional" data, on which conditions for use could be defined and imposed by the producer.(304)

WMO Resolution 40 has created friction between ECOMET and European private sector weather service companies that, prior to ECOMET's formation, had received satellite weather data at no cost on an unrestricted basis. European private sector weather service providers reportedly assert that the ECOMET nations charge unfair prices for satellite data that is subsidized to a large extent by European taxpayers. Private companies also claim that the European National Weather Services has created trade barriers by restricting access to free observational data to the ECOMET member nations and to select academic users such as universities.(305)

Despite these private sector concerns, the commercialization of government weather satellite data is proceeding. In October 1999, the European Commission authorized the sale of commercial products by ECOMET, ruling that there is adequate competition within ECOMET itself and that the "grouping operates in such a way as to permit fair competition with independent providers."(306) The ruling by the European Commission places the ECOMET nations' practices of commercializing government-supplied satellite information at odds with the policies of the U.S. Government. Although the U.S. Government recognizes the right of individual nations to impose restrictions and regulate markets within national territories, it has argued against the explicit adoption of an international policy to limit the flow of weather information. (307) The ECOMET nations have in turn threatened to cut off their supply of weather information to the WMO if the United States fails to prevent the re-export of ECOMET weather data.(308)

E. National Security Implications

Differing national policies on the commercialization of government-supplied weather data could lead to reduced availability of worldwide weather information if countries choose to withhold weather information in retaliation for the re-export of weather data. If this were to happen, negative effects would be unavoidable. In the absence of data from countries declining to supply weather observations, weather models may not be as accurate. Any consequential reduction in quality could affect U.S. use of the data and products for defense, intelligence, civil and commercial applications. For example, U.S. companies involved in value-added weather services and products could experience revenue loss.

The following section discusses legal and regulatory issues and the need for interagency coordination involving all four space sectors.

VII. Interagency Coordination and Legal and Regulatory Environment

A. Interagency Coordination

1. A National Policy Approach

Responsibility and accountability for space generally is diffused throughout the U.S. Government--from the Executive Office of the President to scores of other federal departments and agencies. This arrangement does not allow for focused attention to space matters. Consequently, issues may not necessarily enter the national security apparatus and opportunities may be lost for important dialogue and coordination regarding national security matters. The interdependence of the space sectors requires a more concentrated focus on space.

At the national level, the 1996 National Space Policy designates the National Science and Technology Council (NSTC), a Cabinet-level organization chaired by the President, as "the principal forum for resolving issues related to national space policy. As appropriate, the NSTC and NSC [National Security Council] will co-chair policy processes."(309) The Office of Science and Technology Policy (OSTP) coordinates federal polices for science and technology. The Director of OSTP serves as the Assistant to the President for Science and Technology and supports the NSTC.

Under the Clinton Administration, the principal position within the National Security Council with space responsibility was a Director reporting to the Senior Director, Defense Policy and Arms Control. The position within the Office of Science and Technology Policy was the Assistant Director for Space and Aeronautics reporting to Associate Director for Technology.

It is fundamental to U.S. national security that the United States establishes and implements a national approach for leading the country and coordinating U.S. Government departments and agencies regarding U.S. national security space issues. Space applications in the United States and the world have expanded to virtually every component of society and commerce. The commercial space sector is escalating. New foreign space programs are emerging. Globalization is expanding.

As a result, U.S. policies, laws, regulations and actions in a wide range of areas may affect national security space. Everyday, in domestic and international arenas, U.S. Government representatives enter bilateral and multilateral negotiations, assert U.S. positions, make recommendations and take actions on a plethora of issues that clearly do, or potentially could, involve any or all of the four space sectors and affect U.S. national security interests. Thus, there are a number of space-related arenas in which U.S. national security could be at issue, or worse, at stake.

U.S. Government departments and agencies need guidance and oversight. A timely and effective interagency coordination process is vitally necessary to properly evaluate and implement national security space policies. The United States must actively shape the U.S. and international legal and regulatory environment to further U.S. national security objectives, including enhancing American competitiveness. These actions are necessary to ensure U.S. national security and the success of each of the four space sectors. A coherent and effective interagency process also would promote efficient use of U.S. Government expertise and assets, reduce government costs and save resources. Furthermore, such a process would advance and strengthen the position of the U.S. Government internationally and would provide the nation with confidence in federal government processes and decision making.

2. Pending Agenda Items

The range of domestic and international radio frequency, orbital location and licensing issues facing the United States demand a coherent, national policy approach and deliberate direction. A sample of these pending issues include:

- WTO negotiations regarding market access for commercial satellite systems.
- Domestic allocation of spectrum for third generation wireless (scheduled to occur by July 1, 2001) (310) and the potential authorization of commercial ultrawide band services, both of which may affect Department of Defense use of spectrum for military operations, government use of commercial spectrum and commercial use of government spectrum.
- Claims of developing countries regarding equitable access to radio frequency spectrum and orbital locations.(311)
- Orbital debris and deorbiting policies in the United States and other countries.
- Domestic commercial satellite licensing matters involving national security or law enforcement issues, such as remote sensing policies, export control and foreign ownership.
- Licensing delays and increased difficulty in coordinating commercial satellite systems.

B. Satellite Regulatory Issues

1. Radio Frequency Spectrum and Orbital Locations

All wireless services use, and thus require, radio frequency spectrum. Satellites are just one of these services. Demands for radio frequency spectrum are escalating. This increase is the result of the pro-competitive market-opening effects of the WTO Agreement, as well as new and expanded uses of radio frequency spectrum for various technologies. As a result, the allocation, assignment and coordination of radio frequency spectrum and assignment of orbital locations for government and nongovernment purposes are becoming more difficult and time-consuming.(312)

Today, radio frequency spectrum and orbital location issues are pending on the agendas of various international organizations. Those issues are of strong importance to the United States and virtually every country in the world, including the developing countries, which are increasingly interested in establishing their own satellite systems. These issues matter because radio frequency spectrum and orbital locations are necessary to operate in space. As a result, access to and authority to use those assets have national security, foreign policy, economic, technological and societal implications worldwide.

2. Licensing of Satellite Systems

Licensing of satellite systems provides satellite providers opportunities and obstacles. The increasing globalization of the satellite market magnifies both of these--in market access decisions worldwide. In the United States, under the Administrative Procedures Act,(313) the U.S. Government must provide notice of certain proposed actions and provide the public opportunity to present its views in writing on the record. This deliberative process provides every segment of the public--the U.S. Government, U.S. industry, state and local governments, foreign governments, foreign companies and individuals worldwide--advance notice of policies and decisions that may affect them and opportunity to influence the U.S. regulatory process. By providing for an open and transparent process, this system promotes public confidence and creates investment incentives and rewards. Companies generally cite the relative certainty and fairness of the U.S. regulatory process, as well as its competitive policies as a reason to seek to provide service in the U.S. market. In addition, hundreds of regulators around the globe seek guidance from U.S. regulators about our procedures and policies in an attempt to adopt similar approaches in their countries.(314)

Licensing of commercial communications satellite systems in the United States also presents challenges for both government and industry. The Federal Communications Commission grants licenses and authorizations to commercial communications systems for spectrum frequencies, orbital locations, space stations and ground equipment. In doing so, based on its statutory mandate under the Communications Act of 1934, the agency applies a public interest standard.(315) Given the public participation requirements and increasing complexity of the issues, it can take more than two years to license a satellite system for which there already is an existing allocation and three years or more where there is not an existing allocation.

In the fast-paced commercial communications satellite market, where demands for radio frequency spectrum are high and competition from terrestrial wireless services is strong, time and certainty matter. While applications are pending, technology changes and market dynamics shift. Alternative licensing approaches may speed the length of time to award licenses, and thereby increase government efficiency, reduce government resource costs and enable the public, U.S. businesses and the economy to realize the benefits of competition more quickly.

3. Export Licensing

In March 1999, in response to concerns about the transfer of U.S. satellite-related technology to China, Congress reclassified commercial satellites and related components as munitions under U.S. export licensing laws. Congress also transferred the government licensing function from the Department of Commerce to the Department of State. Since the stricter controls became effective, the volume of export licensing applications has increased and decisions have been delayed.

Some industry observers have claimed that the new export regulations are causing the U.S. satellite industry to turn to foreign providers. (316) The Booz, Allen & Hamilton *2000 Defense Industry Viewpoint* found that while the United States historically has held approximately 70% of the global market for geosynchronous communications satellites, the competitiveness of the U.S. industry in international markets "has been significantly impacted" by the new export control regulations. (317) The study cautions that this segment of the U.S. industry could lose up to $1 billion annually if the export issues are not resolved. (318)

There are some reports that the export licensing process in the United States is improving.(319) That trend should continue. Progress is necessary for the strength of the U.S. commercial space sector as well as the national security space sector as well. "'[I]f weakened U.S. satellite makers cede this market to foreigners, it will jeopardize America's global surveillance, reconnaissance and communications network, the linchpin of the Pentagon's 21st century battle plan."(320)

VIII. U.S. Government Use of Commercial Satellites for National Security

A. Background

The national security space sector includes the defense space sector and intelligence space sector. Space-based technologies and information is an integral component of American military strategy and operations. Ability to communicate and to transmit information is fundamental to defense and intelligence activities and to U.S. national security.(321) These capabilities assist national leaders in implementing foreign policy, managing crises in distant places and conducting military actions. Military strategy and doctrine increasingly focus on information and its potential for improving combat performance. As the *2000 RAND Employing Commercial Satellite Communications Study* recognizes:

> Sufficient capacity for transmitting information must be obtained to support emerging military doctrine, including the uncertainties posed by the unknowable timing of future contingencies.... [C]ommercial systems and services may represent the best opportunity to achieve affordable communications capacity.(322)

U.S. intelligence space activities began in the 1960s, focusing on the USSR. The need for intelligence information continues today, including to collect information on various subjects in support of U.S. global security policy. Given the changing nature of international conflict and U.S. defense strategies, information and the ability to communicate are increasingly critical commodities for national security. U.S. military leaders and ground troops need timely access to quantities of quality intelligence information, imagery and weather data from satellites. They need to communicate that information rapidly via satellite.

The Department of Defense expects military demand for communications to grow over the next decade and beyond.(323) To fulfill its defense and intelligence needs for satellite services and products, the U.S.Government has two main options. One option is to acquire its own satellite assets. Examples of U.S.-owned systems include MILSTAR, Gapfiller and National Reconnaissance Office (NRO) satellites.(324) As an owner, the U.S. Government can operate a satellite system and maintain control over it. As a second option, the U.S. Government can lease satellite capacity from a commercial provider, either in whole or in part.

The commercial space sector provides valuable opportunities for the U.S. Government to execute its national security space missions.(325) "A major tenet of the future architecture and transition strategy is to reduce costs by leveraging advances in commercial satellite communications to the maximum extent practicable."(326) The sector has been providing communications satellite services to the U.S. Government for decades. From 1984-1996, for example, the U.S. Government leased the LEASAT satellite system from Hughes, which operated in the military UHF and X-bands.(327) In addition, the U.S. Government has procured or leased the following commercial satellite systems or products:

- In 1990-91, in Desert Storm, the U.S. Government used commercial satellite communications services and purchased remote sensing imagery from the French company, Spot Image.
- In 1995, the U.S. Navy purchased over two million minutes on the INMARSAT system for narrowband voice and data services to transmit medical data and supply orders.
- In 1996, the U.S. Government used leased capacity on the INTELSAT satellite system as part of a VSAT data network for field commanders in Bosnia and in 1999, leased capacity on an expedited basis for voice, Internet access and videoconferencing in Kosovo.
- The U.S. Army Trojan program has used a commercial satellite system to send communications to Department of Defense locations in the United States and Europe, as well as to Department of State locations overseas.
- On December 5, 2000, the Department of Defense awarded new Iridium Satellite LLC a $72 million contract for 24 months of satellite communications services.(328) In early 2001, Iridium is expected to offer a secure voice capability for existing and new users registered to the Department of Defense gateway, other federal agencies and selected allied governments.(329)
- The Department of Defense currently leases capacity from New Skies Satellites, N.V., a Netherlands company, for communications between the United States and Southwest Asia, as well as in Bahrain and Kuwait.

As government demand for satellite capacity has increased and commercial systems have evolved, government utilization of the commercial satellite sector has received greater attention, particularly regarding commercial satellite imagery, which has developed significantly. In addition to the services and products they provide, commercial systems also are beneficial because they already have orbital locations (in the case of geochronous satellites) and experience working with foreign countries to obtain requisite government approvals to receive and transmit signals to and from foreign countries.(330)

The feasibility and utility of using commercial satellite services and products has been part of numerous studies in recent years, some of which Congress, the Department of Defense or the Armed Services have conducted or authorized.(331) The following section discusses some of these studies and related issues.

B. Commercial Communications Satellite Services

The Department of Defense and the Air Force initiated satellite communications several decades ago.(332) Since then, satellite communications have become "an integral part of military operations--from transmitting a common operational picture to allowing rear-area units to perform otherwise-impossible logistical and intelligence functions."(333)

The Department of Defense satisfies about 60% of its satellite communications needs with commercial satellite systems.(334) The U.S. Air Force estimates that it currently relies on commercial systems for about 50% of its military satellite communications needs and that this figure will rise to 75% in the coming years.(335) According to the *2000 RAND Employing Commercial Satellite Communications Study*, however, "In the near term, there are not enough military systems to satisfy projected communications demand and commercial systems will have to be used. In the future, budgetary pressures will make it difficult for the services to satisfy the projected communications demand with dedicated military assets."(336) The study also finds that although about half of the Department of Defense's projected military satellite communication capacity needs from now until 2010 are for high bandwidth communications, currently programmed military satellite communications systems will not satisfy the demand.(337)

The Defense Information Systems Agency (DISA) is the Department of Defense's lead Agency for leasing commercial satellite services.(338) DISA's mission of providing services is highly dependent on both Department of Defense-owned and commercially-leased satellite communications and support. DISA works closely with the commercial satellite industry to understand the current and emerging systems and services in order to provide the best support to DISA's customers, which include the Armed Services, the CINCs, Department of Defense agencies and the White House Communications Agency. DISA's "TELEPORT Program" leverages existing and emerging military and commercial satellite communications systems. (339)

Several of the studies mentioned above evaluate the viability of using commercial satellite systems.(340) Some of the studies provide satellite need estimates, delineate requisite national security safeguards that must be met for specific operations and explore procurement options and alternatives. Sample eligibility criteria are: sufficient satellite capacity, proper geographic coverage, operational flexibility, interoperability with Department of Defense systems and ground equipment, access to communications services when needed, quality services that meet industry standards or military specifications for reliability and sufficient protection against attack, jamming and other national security risks.

As the studies explain, commercial systems complement military satellites. Commercial systems are not feasible for certain defense and intelligence functions. "Current and planned commercial satellite services will not support some of the Navy's unique requirements, such as communicating with forces under heavy jungle foliage or inside urban buildings."(341) In addition, commercial capacity must be able to provide timely access to information that can be communicated rapidly; "there is an implied expectation that the military will have access to whatever type and amount of communications it requires to support operations."(342)

The *Army Science Board 1999 Summer Study* recommends that "the Army should continue and expand its efforts to exploit commercial systems and space-related technologies."(343) Additional recommendations for utilizing the commercial satellite sector are:

- Evaluate commercial options on a case-by-case basis, taking into account factors such as mission objectives, national security criteria, cost, projected viability of the particular commercial satellite service and feasibility of technological alternatives (e.g., terrestrial wireless or fiber-based systems).
- Consider early U.S. Government involvement as a customer so that commercial satellite system designs can properly address U.S. Government requirements.
- Consider anchor tenancy and other alternative lease arrangements that encourage availability of commercial capacity for U.S. Government use (e.g., commit to purchasing set amount of future service in exchange for commercial company incorporating features to satisfy military requirements in its system design).
- Encourage commercial development of interoperable systems and of hardening and other requisite national security protections. For example, Globalstar, a mobile satellite service provider, reportedly is studying ways to improve encryption, resiliency and compatibility and ways to increase mobility by reducing the size of ground stations and employing truck-mounted gateway facilities.(344)
- Consider alternative lease length terms that make the U.S. Government a more desirable customer.

C. Commercial Satellite Imagery

The U.S. Government may obtain satellite imagery for defense and intelligence purposes either from its own satellites (generally those built and operated by the National Reconnaissance Office) or by purchasing satellite imagery on the commercial market. Since the U.S. Government used commercial imagery in the Persian Gulf War and Kosovo conflict, commercial imagery has improved. Today, the U.S. Government could request commercial remote sensing satellite imaging from a rented trailer in theater and in less than 20 minutes receive an image of a place on the earth in one-meter resolution and bulk imagery is available at discounted prices. As discussed above, recently, commercial providers have been licensed for half-meter imagery, which allows the human eye to see objects as small as an automobile. The U.S. Air Force is now the largest customer of commercial imagery in the world.

NIMA has the statutory responsibility for purchasing all commercial imagery and geospatial products. It also contributes to the policy processes by which the government regulates the commercial imagery industry. A Congressionally-chartered Commission found in a December 2000 Report that NIMA "has been characterized as an unreliable partner."(345) The NIMA Commission made several recommendations regarding NIMA's role, including that: NIMA should advocate commercial imagery, especially where it satisfies a unique need and/or offers unclassified information-sharing opportunities; there should be a senior officer responsible for NIMA's commercial imagery program; users should be empowered to make their own decisions; a commercial imagery fund (which NIMA could administer for the Department of Defense) should be available for end-users to buy raw imagery and a vendor's value-added offerings; there should be a policy review and coherent strategic direction for the use and reliance upon commercial products under the Future Imagery Architecture;(346) and NIMA should play a stronger advocacy role for commercialization, especially in light of consumer demand.(347)

The *Army Science Board 1999 Summer Study* recommends that the Army "[d]evelop an understanding of the availability and use of commercial imagery to support Army tactical users... . includ[ing] not just intelligence and engineering functions but also logistics and other support functions." In addition, the study recommends that the Army determine how commercial imagery systems could supplement standard weather satellite systems to improve forecasting methods, noting that the "Integrated Meterological System should include access to commercial products."(348) Finally, the *Army Science Board 1999 Summer Study* recommends that the Army address tactical needs "by ensuring that commercial geospatial workstation technology is rapidly moved to the field to supplement traditional NIMA products with tailored products that combine terrain data from commercial and other sources."(349)

IX. Conclusions and Recommendations

A. Conclusions

Commercial satellites provide valuable services in the United States and the world. These services allow businesses to operate, people to communicate and governments to serve the public. They also facilitate provisions of communications services provided mainly by other technologies.

Commercial satellite services contribute to U.S. national security in several ways. They provide satellite services and products to the U.S. Government for carrying out national security missions. In addition, use of commercial satellite services and products frees use of government satellites for other defense and intelligence missions more suited for government operation. Commercial satellites provide critical infrastructure to the nation as a whole, support U.S. industry and provide telecommunications and other services to U.S. users. In addition, the sector contributes to the U.S. economy and enhances the space leadership position of the United States in the global space market. Though difficult to quantify in dollars, the value of commercial satellite services to the United States can be measured in different ways: saved lives (voice communications in theater; emergency telephone call in rural parts of the United States); enabling other applications (e.g., satellites enable over-the-air broadcasts); and competitive effects of availability of satellite alternatives (direct broadcast television as effective competitor to cable television, reducing prices and improving programming in cable and DBS markets).

There are several U.S. national security benefits in leveraging the commercial space sector. Greater use of commercial satellite services and imaging products will help solidify the position of U.S. companies in a fiercely competitive international market. Doing so will increase availability of alternative satellite providers and innovative technologies, increasing options for all U.S. consumers, including the U.S. Government. Given the increasing demand for communications and information capabilities, the U.S.Government should continue to pursue commercial options, subject to mission purpose, cost effectiveness and other appropriate factors. At the same time, the Department of Defense should continue to own and operate its own satellite systems to meet unique and critical military needs, as well as because of uncertain economic and market trends.

Though space has been a part of U.S. foreign and military policy for decades, today's combination of greater U.S. reliance on space and international use of space elevates space to an even higher level of importance. Satellite services are integral to American life and commerce, as well as to the national security of the United States. They provide enormous opportunities for growth and for the United States to safeguard the nation's security. At the same time, however, they create vulnerabilities. To be dependent is to be vulnerable. The United States relies more heavily on satellite services than any other country in the world. Satellites are part of the national's critical infrastructure and there are thousands of U.S. satellite ground stations on the earth. Space is within the reach of more nations. Through increased openness and globalization, other countries are gaining greater access to space-based technologies and prominence in the international regulatory environment. Increased capabilities of other countries also creates risks to U.S. national security interests.

To continue to further U.S. national security space objectives, including leveraging the commercial satellite industry, the United States must provide strong U.S. leadership and effective interagency coordination. It also must actively shape the U.S. and international legal and regulatory environment, promote competition in the global commercial satellite services market, and as appropriate, seek international cooperation.

B. Recommendations

To further U.S. national security space objectives, including ensuring U.S. national security and leveraging the commercial space sector, the U.S. Government should consider the following recommendations:

In developing policies regarding U.S. national security, consider the role of the commercial space sector in national security and the implications of any policy (e.g., prospective effect of remote sensing policies on commercial interests; implications of hostilities in space for the commercial satellite sector; effect of foreign ownership and foreign facilities limitations on competitive commercial space sector and U.S. companies).

- In developing policies regarding the commercial space sector, consider U.S. national security and the implications of any policy (e.g., prospective effect of remote sensing policies on national security; effect of foreign ownership and foreign facilities limitations on national security).
- Use more expeditious licensing processes while safeguarding U.S. national security interests. Establish regulatory policies that encourage rather than restrict the availability of space products worldwide, while maintaining U.S. technological lead.
- Given the vital role of space in U.S. national security, provide for national-level guidance that establishes space activity as a fundamental interest of the United States.
- To assure that the United States continues its leadership role in space, a space advisory group could provide independent ideas to the President on ways to capitalize on the nation's investment in people, technology, infrastructure and capabilities in all four space sectors.
- Establish a process to ensure that national-level policy guidance is carried out among and within the relevant agencies and departments. To this end, a standing senior interagency group for space within the National Security Council structure could serve to provide a deliberate, coherent approach to the implementation of national space policy and coordinate national security space matters government-wide. The group could focus on the most critical national security space issues, including those that span the civil and commercial space sectors. The group could have staff support that provides experience across the four space sectors.
- Consider designating a high-level staff responsibility within each U.S. Government agency that has jurisdiction over commercial space and/or national security issues to support the highest-level position in the agency responsible for national security issues. This staff function could include developing and implementing policy; creating initiatives for leveraging the commercial space sector for national security purposes; coordinating with the Department of Defense and other federal agencies; and serving as a liaison with industry.
- Consider that a centralized interagency process could leverage the collective investment in the commercial, civil, defense and intelligence sectors to advance U.S. capabilities in each and account for the increasingly important role played by the commercial and civil space sectors in the nation's domestic and global economic and national security affairs.
- Participate actively and on an on-going basis in the U.S. and international legal and regulatory environment to further U.S. national security space interests, including the commercial space sector. Shape the environment by initiating proposals and advocating changes as appropriate.
- Become a more reliable customer of commercial space products and services. Continue to pursue use of commercial satellite services for U.S. national security purposes as appropriate.
- Implement procurement policies that provide flexibility for the U.S. Government and make the U.S. Government a more reliable and viable customer.

X. Summary

In the days of Galileo, discoverers relied on the constellations to explore the earth. As Daniel Boorstin wrote in The Discoverers:

> The vast sameness of the oceans on the surface naturally drove sailors to seek their bearings in the heavens, in the sun and moon and stars and constellations. They sought skymarks to serve for seamarks.... With the aid of the newly invented telescope fixed on the heavens, ...men discovered the seas, charted the oceans, and defined new continents.(350)

Four hundred years later, today, men and women continue to make new discoveries about space and earth through space. People worldwide are using space-based technologies and services to explore, conduct business, govern, teach, learn and defend their nations. More countries are discovering the virtues of space and developing the economical and technological means of using it. The United States relies on--and benefits from--space applications more than any other nation in the world. Thus, satellites in space are integral to U.S. national security, infrastructure and livelihood.

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Footnotes

(1) See, e.g., "Iridium Rebounds to Win," The Washington Post, 11 December 2000, E1.

(2) For example, companies are using satellite systems to provide network and cyberspace protection services. Peter J. Brown, "Satellite Telephony A Vital Link," Via Satellite (January 2001), 48. (Brown, Satellite Telephony)

(3) Peter S. Goodman, "Dishing Up a New Link to the Internet," The Washington Post, 6 November 2000, A01. Virginia-based StarBand Communications, Inc. is providing two-way satellite Internet service to the Havasupai Indian reservation at the bottom of the Grand Canyon. Ibid.

(4) Gary Sheftick, "Women Ski Across Antarctica Using Army Phone Links," Army LINKS News, 19 December 2000. http://www.dtic.mil/armylink/news/Dec2000/a2001219antarctica.html. A team of two explorers, Ms. Ann Bancroft of the United States and Ms. Liv Arnesen of Norway, are attempting a 2,300 mile,100-day expedition across Antarctica. The explorers are using an Iridium satellite telephone (that the U.S. Army provided) to maintain contact with expedition headquarters in Minneapolis, Minnesota, to conduct live interviews and to communicate with their families, schoolchildren and others. The satellite phone also enables three-way conference calling and text messaging. In addition, the explorers are using the Global Positioning Satellite System, a navigation and location satellite system, to chart their daily courses. The website for the expedition is: http://www.yourexpedition.com.

(5) For example, on December 17, 2000, U.S. Coast Guard helicopters rescued 34 crewmembers from a passenger ship, Sea Breeze I, which was sinking about 200 miles east of Cape Charles, Virginia. "Coast Guard Rescues 34 People Update 1," Coast Guard News, 17 December 2000. Retrieved December 19, 2000, from the World Wide Web: http://www.uscg.mil/d5/news/2000/rl62_00.html. Satellite systems enabled the timely and successful rescue.

(6) Brown, "Satellite Telephony, 42-53 (describes various U.S. and foreign commercial and civil satellite systems and programs that provide emergency and disaster relief, including U.K.-based Surrey Satellite Technology Ltd.'s Disaster Monitoring Constellation, Volunteers in Technical Assistance, UNICEF, U.K.-based Inmarsat, U.S.-based Globalstar and West Virginia-based Chesapeake Satellite) supra, n.2.

(7) "Information and Knowledge ... form the building bricks of the new economy." "A Survey of the New Economy, Untangling e-conomics," The Economist," 23 September 2000 (The Economist Survey), 27. "The rapid growth and critical importance of the telecommunications and information industries will continue for at least the next decade." "NTIA Information," Retrieved Department of Commerce, National Telecommunications and Information Administration (NTIA): http://www.ntia.doc.gov/ntiahome/aboutntia.htm. NTIA is the Executive Branch agency principally responsible for domestic and international telecommunications and information policy issues. Ibid.

(8) "The rapid growth and critical importance of the telecommunications and information industries will continue for at least the next decade, domestically and internationally." NTIA website: http://www.ntia.doc.gov/ntiahome/aboutntia.htm. See also The Economist Survey, 7 ("America has been the first to embrace the IT [information technology] revolution and the new economy [and] this could prove to be the biggest technological revolution ever for the world as a whole"); Merrill Lynch, Satellite Communications: Launching a New Era (August 1, 2000), 64 (Merrill Lynch, Satellite Communications).

(9) Report of the Commission to Assess United States National Security Space Management and Organization, Commission to Assess United States National Security Space Management and Organization (January 11, 2001).

(10) Public Law 106-65 (Oct. 5, 1999), Section 1622, 10 U.S.C. 111 note.

(11) The paper does not cover the satellite manufacturing segment, launch segment or the civil space sector.

(12) Specific offices included: Office of the Assistant Secretary for Command, Control, Communications and Information, Office of Net Assessment, National Security Space Architect, Defense Information System Administration, U.S. Air Force, U.S. Army and U.S. Navy.

(13) Specific offices included: the Bureau of Oceans and International Environmental and Scientific Affairs, Office of Space and Advanced Technology.

(14) Specific offices included: the National Telecommunications and Information Administration and the National Oceanic and Atmospheric Administration.

(15) Specific offices included: Office of Commissioner Michael K. Powell, the International Bureau and the Office of Engineering and Technology.

(16) "Space Almanac," Air Force Magazine (August 2000), 34.

(17) Douglas Aircraft Company, Inc., "Preliminary Design of an Experimental World-Circling Spaceship," Abstract, Report No. SM-11827, (May 1946), 8, 9, 17, 23, quoted in Walter A. McDougall, ... the Heavens and the Earth (New York: Basic Books , Inc., 1985), 102.

(18) National Aeronautics and Space Act of 1958, 42 U.S.C. 2451.

(19) 42 U.S.C. sec. 2451(c)(5).

(20) Public Law No. 624, 87th Congress, 2d Sess., 76 Stat 419, approved Aug. 31, 1962.

(21) 47 U.S.C. sec. 701(a).

(22) Alexandra M. Field, "INTELSAT at Crossroads," Law and Policy in International Business, Vol. 25,No. 4 (Summer 1994): 1335-66.

(23) The INTELSAT website is: http://www.intelsat.int.

(24) 47 U.S.C. sections 701-757. See Comsat Study--Implementation of Section 505 of the International Maritime Telecommunications Act, C.C. Docket No. 79-266, FCC 80-218 (1980).

(25) 47 U.S.C. sec. 701(c).

(26) INTELSAT LLC, Memorandum Opinion Order and Authorization, FCC 00-287 (August 8, 2000).

(27) Ibid.,1, n.10 citing Policy for the Distribution of United States International Carrier Circuits Among Available Facilities During the Post-1988 Period, 3 FCC Rcd 2156 (1988).

(28) Memorandum for: Hon. Dean Burch, Chairman, Federal Communications Commission from Mr. Peter Flanigan, Assistant to the President (The White House, Washington, D.C., January 23, 1970) as reproduced in Establishment of Domestic Communication-Satellite Facilities by Nongovernmental Entities, 22 FCC 2d 86, 125 (1970) (Domsat I).

(29) Domsat I, 22 FCC 2d at 128.

(30) Domsat II, 35 FCC 2d 844 (1981).

(31) See, e.g., Separate Satellite Systems, 101 FCC 2d 1046 (1985).

(32) INTELSAT LLC, Memorandum Opinion Order and Authorization, FCC 00-287 (August 8, 2000), 11, citing Direct Access to the INTELSAT System, Report and Order, 14 FCC Rcd 15703, 15759 (1999) (stating support for privatization and citing the Statement of Administration Position by Ambassador Vonya B. McCann, United States Coordinator, International Communications and Information Policy, Department of State, before the Senate Committee on Commerce, Science and Transportation, Subcommittee on Commerce (March 25, 1999)) .

(33) Public Law 106-180, 114 Stat. 48 (2000). ORBIT also includes privatization and entry criteria for Inmarsat and spin-offs of the two organizations.

(34) INTELSAT LLC, Memorandum Opinion Order and Authorization, FCC 00-287 (August 8, 2000).

(35) Ibid., 3.

(36) See, e.g., John R. Harbison, General Thomas S. Moorman, Jr. (USAF Retired), Michael W. Jones, Jikun Kim, Booz, Allen & Hamilton, Viewpoint, "U.S. Defense Industry Under Siege--An Agenda for Change," (2000), 3 (stating that top line revenues for the U.S. defense are projected to be stable, and even growing slightly, after a twelve-year period of declines linked to the fall of the Berlin Wall, outbreak of peace, changes in priorities under the Clinton Administration and government procurement policies) (Booz, Allen & Hamilton, 2000 Defense Industry Viewpoint).

(37) International Space Business Council, State of the Space Industry 2000 (2000), 10 & 24 (ISBC, Space Industry 2000).

(38) C.E. Unterberg, Towbin, Satellite Communications 2001 Outlook and Investment Guide (January 21, 2001), 5 (C.E. Unterberg, Towbin, Satellite Communications 2001Outlook). C.E. Unterberg, Towbin assessed and ranked twelve segments of the satellite industry: satellite television, international satellite television, satellite radio, capacity leasing, Very Small Aperture Terminals (VSATs), satellite imaging, manufacturing, earth stations, satellite Internet Service Providers, launch services, telephony and satellite messaging.

(39) ISBC, Space Industry 2000, 17.

(40) Satellite Industry Association and Futron, with cooperation from World Teleport Association, The Space Transportation Association, Global VSAT Forum and Society of Satellite Professional International, Satellite Industry Indicators Fact Sheet (June 5, 2000), 3 (Satellite Industry Fact Sheet).

(41) Ibid.

(42) Ibid., 4.

(43) Ibid.

(44) ISBC, Space Industry 2000, 17, supra n.37.

(45) ING Barings, The Satellite Communications Industry: Efficient Infrastructure 2000 (March 2000), 7 (ING Barings, Satellite Communications). This estimate includes communications satellite services, manufacturing and launch. It excludes government systems and services.

(46) See, e.g., Merrill Lynch, Satellite Communication, 64, supra n.8.

(47) Prepared Statement by Dr. John J. Hamre, Deputy Secretary of Defense, Hearing before the U.S. Senate, Subcommittee on Strategic, Committee on Armed Forces regarding the Department of Defense Authorization for Appropriations for Fiscal Year 2000 and the Future Defense Program (Colorado Springs, March 22, 1999), 287-289 (1999 Prepared Statement by Dr. Hamre).

(48) A National Security Strategy of Engagement and Enlargement, the White House (December 1999), Part II, p. 12 (1999 National Security Strategy).

(49) Ibid. Part I, p. 1.

(50) "National Space Policy," Fact Sheet, Presidential Policy Directive (PDD) 49, (The White House, National Science and Technology Council) (September 19, 1996) (National Space Policy Fact Sheet), 1.

(51) National Space Policy Fact Sheet, 1.

(52) Ibid., 4.

(53) Ibid., 5.

(54) Ibid., 8.

(55) Ibid. "`Feasible' means that such goods or services meet mission requirements in a cost-effective manner." Ibid.

(56) The White House, "White Paper, The Clinton Administration's Policy on Critical Infrastructure Protection: Presidential Decision Directive 63," (May 1998) (Critical Infrastructure Protection Policy White Paper). Retrieved October 21, 2000, from the World Wide Web: http://www.whitehouse.gov/WH/EOP/NSC/html/documents/NSCDoc3.html.

(57) Ibid., 8. The Critical Infrastructure Protection Policy designates U.S. lead agencies for responsibility for the specified critical infrastructures, including, for example: Department of Defense--national defense; Central Intelligence Agency--foreign intelligence; Department of State--foreign affairs; Department of Commerce--information and communications; Department of Transportation--aviation and highways (including trucking and intelligent transportation systems); Department of Justice and Federal Bureau of Investigation--law enforcement services; Federal Emergency Management Administration--emergency fire service and continuity of government services. The National Telecommunications and Information Administration (within the Department of Commerce) is the lead agency for protecting the U.S. information and communications infrastructure from purposeful cyber or physical attack. Critical Infrastructure Protection Policy White Paper, 8-9.

(58) President's Commission on Critical Infrastructure Protection, "Critical Foundations Protecting America's Infrastructures, The Report of the President's Commission on Critical Infrastructure Protection," 13 October 1997, A-2 (stating that the U.S. information and communications infrastructure sector includes the Public Telecommunications Network (PTN), the Internet, and computers and that the "PTN includes the

landline networks, of the local and long distance carriers, the cellular networks, and satellite service") (1997 Critical Infrastructure Report).

(59) Ibid., A-2.

(60) Ibid., A-3.

(61) Critical Infrastructure Protection Policy White Paper, 2, supra n.56.

(62) 1997 Critical Infrastructure Report, A-27, A-34, supra n.58.

(63) Ibid., A-19.

(64) Critical Infrastructure Protection Policy White Paper, 1, supra n.56.

(65) 1997 Critical Infrastructure Report, A-19, supra n.58.

(66) Critical Infrastructure Protection Policy White Paper, 1-2, supra n.56.

(67) Ibid., 2. The Directive also establishes a "public-private partnership" to reduce vulnerability and establishes an interagency coordination process.

(68) 1997 Critical Infrastructure Report, A-2 to A-6, supra n.58.

(69) Michael J. Martinez, "The Satellite Fix is In," ABCNEWS.com, (May 22, 1998). Retrieved December 19, 2000, from the World Wide Web: http://abcnews.go.com/sections/tech/DailyNews/satellite980519.html.

(70) The AssureSat website is: http://www.assuresat.com.

(71) Peter B. De Selding, "Rescuing Satellites Turns Into Growing Business at Hughes," Space News 11 December 2000, 1.

(72) The photographic equipment onboard remote sensing satellites can be either film-based or electro-optical, which converts the reflected radiation into electrical signals that can be transmitted digitally.

(73) Control of the Landsat program passed to NOAA at the end of 1979.

(74) General Thomas S. Moorman, Jr., USAF, Retired, "The Explosion of Commercial Space and the Implications for National Security," Air Power Journal (Spring 1999). Retrieved October 17, 2000, from the World Wide Web: http://www.airpower.maxwell.af.mil. The article is based on the author's lecture presented to the National Convention of the American Institute of Aeronautics in Reno, Nevada, January 13, 1998.

(75) Lawrence W. Fritz, "Commercial Aspects of Space Remote Sensing Including Spin-Off Benefits," Background Paper in Space Benefits for Humanity in the Twenty-First Century (United Nations, 1999), 173.

(76) Ibid.

(77) In 1998, Frost & Sullivan estimated space-based revenues to be $140 million, compared to about $2.2 billion for the aerial remote sensing segment. Space Imaging Corporate Overview, 2000, http://www.spaceimaging.com.

(78) Ibid.

(79) The Teal Group forecasts that 43 commercial imaging satellites will be launched during 2001-2010. "Teal Forecasts 43 New Commercial Imaging Satellites Valued at $3.62 Billion to be Built and Launched During 2001-2010," PR Newswire, 23 August 2000.

(80) Robert K. Ackerman, "Geospatial Information Market Poised for Geometric Growth," Signal Magazine, (August 1998). Retrieved October 17, 2000, from the World Wide Web: http://www.us.net/signal/Archive/Aug98/geospatial-aug.html.

(81) John R. Copple, Letter to Senator Bill Frist, Senate Commerce Subcommittee on Science, 27 February 1998.

(82) Ibid.

(83) The National Imagery and Mapping Agency (NIMA), for example, notes that OrbView-2 and the Indian IRS-1C satellites are used for disaster assessment for hurricanes and tornadoes. Laura Robinson, NIMA Commercial Imagery Program, Slide Presentation to the 3rd National Space Forum, 2 June 1999.

(84) Joanneum Research Institute, Overview of High Resolution Optical Satellite Systems, http://www.dib.joanneum.ac.at.

(85) Compiled by Stephanie G. Rosenfeld, "Marketplace," Space News, 21 February 2000. Retrieved October 31, 2000, from the World Wide Web: http://www.search.mconetwork.com/smembers/sarch/sarch00/SN0221V.HTM.

(86) Hall, Dorothy K., "Satellite Remote Sensing (Imaging)." Retrieved October 31, 2000, from the World Wide Web: http://chht-ntsev.er.usgs.gov/Glacier_wkshp/srs.htm.

(87) Canadian Space Agency, RADARSAT Background, http://www/space.gc.ca.

(88) Jason Bates, "RDL Nabs First License for U.S. Radar Satellite," Space News Online: This Week, 22-28 June 1998. Retrieved October 31, 2000, from the World Wide Web: http://www.space.edu/mailing-lists/forum/msg00599.html.

(89) "RDL Cedes Satellite License in Response to Fraud Allegations," Space News, 14 November 2000. Retrieved November 14, 2000, from the World Wide Web: http://www.spacenews.com/smembers/sweek/index.html.

(90) The German Ministry of Defense is developing a four-six satellite constellation of SAR-Lupe satellites for military applications through OHB-System of Bremen and Astrium GmbH of Munich. Peter B. de Selding, "German Satellite Plan Could Reignite French Partnership," Space News, 26 June 2000. Retrieved from the World Wide Web: http://www.search.mconetwork.com.

(91) Peter B. de Selding, "Germany Plans to Use X-Band Technology for Commercial Imaging," Space News, 6 March 2000. Retrieved October 31, 2000, from the World Wide Web: http://www.search.mconetwork.com/smembers/sarch/sarch00/sn0306j.htm.

(92) Space Imaging Corporate Overview, http://www.spaceimaging.com. The main investors in Space Imaging are the U.S. companies Lockheed Martin and Raytheon. Additional investors include these foreign entities: Mitsubishi Corporation of Japan, the Swedish Space Corporation, Europe's remote sensing affiliates, Hyundai of South Korea, Van Der Horst Ltd. of Singapore and Thailand's Loxley Public Company Ltd.

(93) Orbimage, http://www.orbimage.com.

(94) Jason Bates, "U.S. Approves Licenses for Two Imaging Satellites with Half-Meter Resolution," Spacenews.com, 18 December 2000, http://www.space.com/businesstechnology/business/satellite_licenses_001218.html.

(95) Andrew Koch, "Space Imaging Gets .5m Go Ahead," Jane's Defence Weekly, 10 January 2001.

(96) Lawrence W. Fritz, "Commercial Aspects of Space Remote Sensing Including Spin-Off Benefits," 172.

(97) Spot Image's main shareholders are CNES (35%), Matra Marconi Space (23%), the French National Geographic Institute (10%), and entities in Belgium, Sweden and Italy (combined share of 11%). The Spot Image website is: http://www.spotimage.fr.

(98) Spot 5, which is scheduled to be launched on an Ariane booster in 2002, will provide five-meter resolution for panchromatic images and 10 meters for multispectral images. CNES-supplied information on the Spot program (1999), http://www.cnes.fr.

(99) "World Survey of Remote Sensing Satellites," Air and Cosmos/Aviation International, 4 April 1997. FBIS translation FTS19970801001299.

(100) Spot Image mission statement, http://www.spotimage.fr.

(101) Brown, Satellite Telephony, 42-44, supra n.2.

(102) "Progress of Japanese Satellite," Asian Office of Aerospace Research and Development (AOARD), http://www.nmjc.org/aoard/jsatellite.html.

(103) A 1969 Japanese Diet resolution allows NASDA to cooperate with Japanese companies on commercial programs that are not expressly military in nature. Kyle T. Umezu, "EarlyBird Tweaks the Law," Japan Space Net, 1997, http://www.spacedaily.com.

(104) Gerald Steinberg, "Dual Use Aspects of Commercial High-Resolution Imaging Satellites," Mideast Security and Policy Studies, No. 37, Section IV, February 1998.

(105) IRS-P6, also called Cartosat-1, is scheduled for launch in 2001-2002. See "World Survey of Remote Sensing Satellites," Air and Cosmos/Aviation International, April 4, 1997. FBIS translation FTS19970801001299. Additional information on IRS satellites is available from the Indian Space Organization website, http://www.isro.org.

(106) "Worldwide Survey of Remote Sensing Satellites," Air & Cosmos/Aviation International, April 4, 1997. FBIS translation FTS19970801001299.

(107) Marco Caceres, "Focus Sharpens for Imaging Satellite Market," Aerospace America, September 2000, 18.

(108) West Indian Space intends to offer one-meter imagery at a substantial discount to imagery obtained from Space Imaging's Ikonos satellites, which Israeli industry considers to be its greatest competitor. Amnon Barzilay, "Israel: Launch of First Eros Satellite Postponed," Ha'aretz, December 30, 1999. FBIS Translation FTS20000102000353.

(109) Sovinformsputnik, http://www-com.iasis.svetcorp.net.

(110) "Kosmos Satellite Reaches Orbit, Starts Operation," Interfax, February 18, 1999. FBIS translation FTS19980218001178.

(111) China is responsible for about 70% of the costs of the joint program. "China-Brazil EO Bird Alive and Well In Orbit," SpaceDaily, 3 February 2000. Retrieved October 28, 2000, from the World Wide Web: http://www.spacer.com/news/china-00d.html.

(112) "China Launches Remote Sensing Satellite," SpaceViews, 1 September 2000. Retrieved October 28, 2000, from the World Wide Web: http://www.spaceviews.com/2000/09/01a.html.

(113) White House Press Release, "Foreign Access to Remote Sensing Space Capabilities," Fact Sheet, 10 March 1994.

(114) ALOS is thought to be scheduled for launch about 2002. John C. Baker, "High Expectation: Japan Bolsters Its Imaging Satellite Capability," Centre for Defence and International Security Studies, Guest Columnist section (May 14, 1999), http://www.cdiss.org.

(115) Kyle T. Umezu, "EarlyBird Tweaks the Law," Japan Space Net, 1997, http://www.spacedaily.com.

(116) The firing of a North Korean Taepo Dong missile over the territory of Japan in August 1998 has galvanized public opinion about developing additional defense capabilities such as observation satellites. The Japanese government is planning to introduce four reconnaissance satellites, two with optical sensors in the one meter range and two with SAR in the one-three meter range. Japan Defense Agency, Defense of Japan 1999 (Japan: Urban Connections, 1999), 207.

(117) "Vajpayee Laud's ISRO's Space Program," Deccan Herald, November 2, 1998. FBIS translation FTS19981102001620.

(118) India hopes to attract business by offering its space launch capabilities at lower prices than American or European facilities. It has signed agreements, for example, to launch South Korean satellites. "Commentary Notes Scope for Commercial Use of Space," All India Radio General Overseas Service, September 30, 1997. FBIS translation FTS19970930000411.

(119) West Indian Space's biggest client is the Israeli Defense Ministry, but the company, expects to sell commercial imagery to defense ministries of other countries. Amnon Barzilay, "Israel: Launch of First Eros Satellite Postponed," Ha'aretz, December 30, 1999. FBIS Translation FTS20000102000353.

(120) Jonathon Ball, Trends in Commercial Space in 1996: Satellite Remote Sensing. Retrieved October 17, 2000 from the World Wide Web: http://www.ta.doc.doc.gov/oasc/tics/rmtsens.htm.

(121) This restriction is based on the Kyl-Bingaman amendment to the Fiscal Year 1997 DoD Authorization bill. Dee Ann Davis, "Shutter Control Rattles Industry," Geo Info Systems, September 1999, http://www.geoinfosystems.com.

(122) Established in 1996, NIMA provides the U.S. Government, including the Department of Defense and the Intelligence Community, imagery and geospatial information.

(123) Andrew Koch, "Space Imaging Gets .5m Go Ahead," Jane's Defence Weekly, 10 January 2001.

(124) Ibid.

(125) Independent Commission on the National Imagery and Mapping Agency, "The Information Edge: Imagery Intelligence and Geospatial Information in an Evolving National Security Environment," Report of the Independent Commission on the National Imagery and Mapping Agency, Final Report (December 2000) (2000 NIMA Commission Report).

(126) Ibid., 15.

(127) Three satellites are required to "fix," or locate a position, and a fourth determines the precise time of the fix.

(128) Jonathon Ball, et. al. "Positioning and Navigation with GPS," 1997. Retrieved October 15, 2000, from the World Wide Web: http://www.comlinks.com.

(129) "U.S. Improves Quality of GPS Signals," SpaceViews, 2 May 2000. Retrieved October 15, 2000, from the World Wide Web: http://www.spacenews.com.

(130) Department of Defense, "Global Positioning System (GPS) 2000," Report to Congress (October 2000), 2 (DOD, 2000 GPS Report to Congress).

(131) ISBC, Space Industry 2000, 17, supra n.37.

(132) GPS revenues are estimated at $16 billion in 2005, compared to direct-to-home revenues at about $36 billion, and broadband revenues at about $15 billion. Ibid.

(133) DOD, 2000 GPS Report to Congress, 9-10, supra n.130.

(134) International Trade Administration, Global Positioning System: Market Projections and Trends in the Newest Global Information Utility (September 1998), 5.

(135) The tracking segment is expected to grow almost as large as the car navigation segment within a few years.

(136) "Coast Guard Rescues 34 People Update 1," Coast Guard News, 17 December 2000. Retrieved December 19, 2000, from the World Wide Web: http://www.uscg.mil/d5/news/2000/rl62_00.html.

(137) The FAA's GPS Transition Plan estimated the operations and maintenance (O&M) costs of the existing aircraft navigation systems at $200 million per year, compared to an O&M cost of about $80 million for the GPS-based system. GPS Transition Plan, Federal Aviation Administration Office of System Architecture and Investment Analysis, 30 October 2000, Chapter 4, p.14. Retrieved October 30, 2000, from the World Wide Web: http://www.faa.gov/asd/gpstrans.htm.

(138) Paula Shaki Trimble, "FAA Slows GPS Plans," Federal Computer Week (27 March 2000). Retrieved October 30, 2000, from the World Wide Web: http://www.fcw.com./fcw/articles/2000/0327/news-faa-03-27-00.asp.

(139) Paula Shaki, "GPS Poses Marketing Challenge," Space News, 15 February 1999, 10. Retrieved October 29, 2000, from the World Wide Web: http://search.mconetwork.com/smembers/sarch/sarch99/sno215fg.htm.

(140) "Trimble Brings GPS Precision to Agriculture," Space Daily, 8 February 2000. Retrieved October 30, 2000 from the World Wide Web: http://www.spacedaily.com/news.

(141) For example, GPS can help reduce "Guess rows" refer to the portions of a field that may be missed or where wasteful overlap may occur as the equipment makes pass after pass in a field. Ibid.

(142) The Applied Research Laboratories at the University of Texas has developed a prototype GPS-based bridge monitoring system. Keith Duff and Michael Hyzak, "Structural Monitoring with GPS," Public Roads, (Spring 1997). Retrieved October 29, 2000, from the World Wide Web: http://www.tfhrc.gov/pubrds/spring97/gps.htm.

(143) "Trimble Offers Internet GPS Time Standard," SpaceDaily, 3 August 1999. Retrieved October 30, 2000, from the World Wide Web: http://www.spacedaily.com.

(144) Paula Shaki, "GPS Firms Capitalize on Boom in Timing Market," Space News, 7 September 1998, 22.

(145) ISBC, Space Industry 2000, 44, supra n.37.

(146) Scott Pace and James E. Wilson, Global Positioning System: Market Projections and Trends in the Newest Global Information Utility, International Trade Administration, Office of Telecommunications, U.S. Department of Commerce (September 1998), 40.

(147) Ibid., 29.

(148) The Japanese OEM companies, the major users, and the Ministry of Posts and Telecommunications, as well as the Japan National Police Agency, belong to the Japan GPS Council, which is the counterpart of the U.S. GPS Industry Council. Ibid., 29.

(149) DOD, 2000 GPS Report to Congress, 1-2, supra n.130.

(150) Council of the European Union, Council Resolution On the Involvement of Europe in a New Generation of Satellite Navigation Services--Galileo Definition Phase, 19 July 1999.

(151) The European Commission, Galileo Definition Phase: Initial Results, 7 June 2000, 20.

(152) Ibid., 21.

(153) Sandra I. Erwin, "Europe's Galileo Plans to Challenge U.S. GPS Dominance," National Defense Industrial Association Feature (June 2000).

(154) ING Barings, Satellite Communications, 7, Exhibit 1-3, supra n.45. This figure includes expected revenues from broadband, U.S. Direct Broadcast Satellite Services (DBS), Direct-to-Home (DTH) Satellite Service, international DBS/DTH, Digital Audio Radio Satellite Service, Mobile Satellite Service, Fixed Satellite Service, Very Small Aperture Terminals (VSATs), Little Low Earth Orbit Satellites and Manufacturing and Launch Services.

(155) See, e.g., Booz, Allen & Hamilton, 2000 Defense Industry Viewpoint, supra n.36 (stating that many companies such as GM Hughes Electronics are "now focusing on the higher growth/higher return businesses of satellite services"); ISBC, Space Industry 2000, 10, supra n.37 ("the satellite services market is experiencing tremendous growth").

(156) See, e.g., Merrill Lynch, Satellite Communications, supra n.8; ING Barings Satellite Communications, supra n.45; James M. Gifford, "Analysts Predict Industry Growth Via Internet," Space News, 4 December 2000, 8 ("Analysts expect the global growth of the Internet to provide healthy revenues for commercial satellite communications companies over the next couple of years").

(157) Futron Corporation's 10 Year Commercial Satellite Forecast (October 2000). These figures are based on demand forecasts for communications services in 42 geographic areas of the world, taking into account projected infrastructure buildout, regulatory environment and other factors. The figures exclude remote sensing and navigation satellite services.

(158) Ibid.

(159) ING Barings, Satellite Communications, 22-23, supra n.45. ING Barings cites the following advantages of satellites: distance and terrain insensitivity (making satellites "ideal solutions" for broadband services to remote or underdeveloped areas where terrestrial technologies are not cost effective or geographically feasible); satellite systems avoid interruptions that frequently occur over congested terrestrial networks; satellites easily can be designed to deliver bandwidth on demand to users within a coverage area; satellites are the "most cost-effective" solution for providing broadband services on a global basis because terrestrial systems are significantly more expensive to deploy worldwide; satellites can be deployed more rapidly than terrestrial alternatives (three-five years). ING Barings notes that higher-powered transmission capabilities, narrow spot beams and improvements in switching technologies could make satellite systems competitive (or at least an alternative) to terrestrial communications systems. See also Merrill Lynch, "Eye in the Sky: 4Q00 Preview," 9 January 2001, 9 (Merrill Lynch, 4Q00 Preview).

(160) http://www.hsc.com/factsheets/376/earlybird.

(161) James M. Gifford, "Analysts Predict Industry Growth Via Internet," Space News, 4 December 2000, 8.

(162) Merrill Lynch, Satellite Communications, 63, supra n.8. VSATs are best-suited for situations in which the transmission from the hub to the remote site is faster than that from the remote sites to the hub. Ibid.

(163) Merrill Lynch, Satellite Communications, 65-66, supra n.8.

(164) http://www.panamsat.com/serv/vsat.htm. Private businesses and corporations also access satellites directly. Walgreens, for example, links more than 2,000 store locations using PanAmSat's Galaxy VI domestic U.S. satellite to relay voice and data communications via dedicated transmission links, enabling inventory tracking, interoffice e-mail, point-of-purchase transactions and other functions. Ibid.

(165) James Careless, "A Look Ahead: 2001's Triumphs and Tribulations," Via Satellite (January 2001), 38.

(166) Ibid., 40 quoting Dianne VanBeber, Vice President of Investor Relations, Gilat.

(167) For example, C.E. Unterberg Towbin cites reservations about some satellite economic models because satellites are generally the most expensive form of high-speed two-way connectivity. C.E. Unterberg, Towbin, Satellite Communications 2001 Outlook, 143, supra n.38.

(168) Specifically, in August 1999, Iridium filed for bankruptcy and on March 17, 2000, announced that it was ceasing service. After obtaining new investors and insurance arrangements, in late 2000, Iridium emerged as a new commercial enterprise--Iridium Satellite LLC of Arnold, Maryland.

(169) "ICO-Teledesic Global Announces Investment Agreements Totaling More Than $1 Billion," Teledesic Press Release (July 11, 2000). Retrieved November 13, 2000, from the World Wide Web: http://www.teledesic.com/newsroom/articles/2000-7-11_ITGLinvestment.htm.

(170) The Motient website is: http://www.motient.com.

(171) ING Barings, Satellite Communications, 20, supra n.45; Merrill Lynch, Eye in the Sky: 3Q00 Preview, 4 October 2000, 2.

(172) Merrill Lynch, 4Q00 Preview, 9 supra n.159; ING Barings, Satellite Communications, 20-21, supra n.45. It is estimated that over 75% of all Internet content exists on computers in the United States and that 90% of all Internet traffic originates, terminates or passes through the United States. This results in an imbalance of Internet flow because large quantities of data exit the United States while smaller amounts remain in the United States. Ibid.

(173) Merrill Lynch, 4Q00 Preview, 1, supra n.159.

(174) ING Barings, Satellite Communications, 13.

(175) C.E. Unterberg, Towbin, Broadband Over Satellite, Industry Update, 12 October 2000, 3.

(176) PanAmSat operates the largest fleet of commercial communications satellites in the world. Its fleet has 21 satellites and upon the successful launch of two additional satellites in the first half of 2001, will expand to 23 satellites.

(177) http://www.panamsat.com/serv/internet.htm.

(178) The Loral website is: http://www.loral.com/overview.overview.html.

(179) The Africa Online website is: http://www.africaonline.com. Africa Online was founded in 1994 by three Kenyans studying at Massachusetts Institute of Technology and Harvard University. It provides Internet services to thousands of individuals and businesses throughout the African continent.

(180) ING Barings, Satellite Communications, 21, supra n.45.

(181) "ICO-Teledesic Global Announces Investment Agreements Totaling More thank $1 Billion," Teledesic Press Release (July 11, 2000). Retrieved November 13, 2000, from the World Wide Web: http://www.teledesic.com/newsroom/articles/2000-7-11_ITGLinvestment.htm.

(182) This terminology reflects differences in the parts of the radio frequency spectrum used to provide the service and difference in the size of the receiving dishes.

(183) Merrill Lynch, Satellite Communication, 3, 209-29, supra n.8; ING Barings, Satellite Communications, 344-50, supra n.45.

(184) C.E. Unterberg, Towbin, Satellite Communications 2001 Outlook, 58, supra n.38.

(185) Ibid, 61-62.

(186) ING Barings, Satellite Communications, 7, 54, supra n.45.

(187) Ibid.

(188) Merrill Lynch, 4Q00 Preview, 9, supra n.159.

(189) Ibid., 3.

(190) http://www.eutlesat.org/about_eutlesat/rub_part1.htm.

(191) ING Barings, Satellite Communications, 54-55, supra n.45.

(192) XM Satellite Radio website: http://www.XM Radio.com; Sirius Radio website: http://www.Sirius Radio.com.

(193) C.E. Unterberg, Towbin, Satellite Communications 2001 Outlook, 15, supra n.38.

(194) Ibid.

(195) "Partnership Would Bring Satellite Radio to Europe," Space News, 8 January 2001, 2.

(196) See, e.g., Extending Wireless Telecommunications Services to Tribal Lands, WT Docket No. 99-266, Report and Order and Further Notice of Proposed Rulemaking, FCC 00-209 (released June 30, 2000); Promoting Deployment and Subscribership in Unserved and Underserved Areas, Including Tribal and Insular Areas, CC Docket No. 96-45, Twelfth Report and Order, Memorandum Opinion and Order and Further Notice of Proposed Rulemaking, FCC 00-208 (released June 30, 2000).

(197) Establishment of Policies and Service Rules for the Mobile Satellite Service in the 2 GHz Band, Report and Order, IB Docket No. 99-81 (August 25, 2000), par. 33.

(198) "Call Africa, and Wait and Wait ...," The Economist, 25 November 2000, 53.

(199) See, e.g., "Crew of 18 Rescued Off Chilean Coast Using ORBCOMM Satellite Network," Company News Release, 11 September 2000. Retrieved October 8, 2000, from the World Wide Web http://www.orbcomm.com.newsroom/latestnews/pr-09-11-00.htm. ORBCOMM is a Virginia-based commercial satellite company using a low-earth orbit constellation.

(200) Brown, Satellite Telephony, 42-53, supra n.2 (describes various U.S. and foreign commercial and civil satellite systems and initiatives for emergency and disaster relief, including U.K.-based Surrey Satellite Technology Ltd.'s Disaster Monitoring Constellation, Volunteers in Technical Assistance, UNICEF, U.K.-based Inmarsat, U.S.-based Globalstar and West Virginia-based Chesapeake Satellite).

(201) In the United States, satellite telephones are not yet required to be equipped with 911capability. Basic 911 is the delivery of emergency 911 calls to a Public Safety Answering Point (PSAP). A PSAP is a point that has been designated to receive 911 calls and route them to emergency service personnel. Enhanced 911includes additional features such as the automatic routing of the caller's location and telephone number. The Federal Communications is addressing applicability of 911 features to mobile satellite service telephones in a pending proceeding. "International Bureau Invites Further Comment Regarding Adoption of 911 Requirements for Satellite Services," IB Docket No. 99-67, DA 00-2826 (December 15, 2000). See also Establishment of Policies and Service Rules for the Mobile Satellite Service in the 2 GHz Band, Report and Order, IB Docket No. 99-81 (August 25, 2000), par. 117-127 (as an interim measure, requiring labels on mobile satellite telephones notifying consumers that the phones do not have 911 emergency capability).

(202) See, e.g., Satellite Industry Association and Satellite Broadcast and Communications Association, The Global Satellite Industry, Proven Success and Failure (October 2000) (SBCA & SIA, Global Satellite Industry).

(203) See supra Section II.C.

(204) SBCA & SIA, Global Satellite Industry, supra n. 202.

(205) Rob Fernandez, "Global Satellite Survey," Via Satellite (July 2000), 36 (referring to Futron figures).

(206) SBCA & SIA, Global Satellite Industry, supra n. 202.

(207) Ibid.

(208) Brown, Satellite Telephony, 48, supra n.2.

(209) Ibid.

(210) Department of Commerce, National Telecommunications and Information Administration (NTIA), http://www.ntia.doc.gov/ntiahome/aboutntia.htm.

(211) Decision making within these organizations involves consensus of up to over 140 different Members, many of whom do not have commercial experience. Consequently, intergovernmental satellite organizations customarily have not been able to make and implement business strategies as quickly as private companies, a significant disadvantage in the fast-paced global telecommunications market.

(212) See, e.g., Agreement Relating to the International Telecommunications Satellite Organization, "INTELSAT," 23 U.S.T. 4091 (February 12, 1973); Operating Agreement Relating to the International Telecommunications Satellite Organization, "INTELSAT," 23 U.S.T. 3813 (August 20, 1971).

(213) The organizations generally have three organs: a large body consisting of all of the government representatives ("parties"), a board of directors of commercial entities and a management body. In countries in which the government owns and operates the telecommunications systems and use the services of it, the representatives generally are the same entity, giving rise to potential conflicts of interest.

(214) Inmarsat Website: http://www.inmarsat.org/about2/aboutint.html.

(215) EUTELSAT website: http://www.eutelsat.org/about_eutelsat/rub_part1.htm. EUTELSAT will transfer all of its assets and activities to a new private company (based in France) and establish a separate intergovernmental organization to ensure that the company observes basic principles of pan-European coverage, universal service, nondiscrimination and fair competition.

(216) "Historic Assembly Says 'All Systems Go' for 2001: INTELSAT Privatization Plan and Schedule Formally Approved by Governments," http://www.intelsat.int/news/press.

(217) The commitments that the signing countries made as a result of the WTO negotiations on basic telecommunications services are incorporated in the General Agreement on Trade in Services by the Fourth Protocol to the GATS. Fourth Protocol to the General Agreement on Trade in Services (WTO 1997), 36 I.L.M. 354, 366 (1997). These commitments generally are referred to as "the WTO Basic Telecom Agreement," which is not a separate, stand-alone agreement. Laura B. Sherman, "Wildly Enthusiastic' About the First Multilateral Agreement on Trade in Telecommunications Services," Federal Communications Law Journal, Vol. 51, No. 1 (December 1998): 62, n.2.

(218) The WTO telecommunications commitments of other countries varied in terms of types of services covered, nature of commitments and effective date of commitments. Any country may accelerate implementation of its commitments or improve them. The WTO Agreement does not limit the right of any WTO Member to manage spectrum, including the ability to allocate frequency bands taking into account existing and future needs.

(219) DBS, DTH and DARS services were excluded from U.S. commitments. The United States also agreed to competitive safeguards such as impartial regulatory treatment and nondiscriminatory allocation and use of scarce resources.

(220) Amendment of the Commission's Regulatory Policies to Allow Non-U.S. Licensed Space Stations to Provide Domestic and International Satellite Service in the United States, 12 FCC Red 24094 (1997) (DISCO II).

(221) General Agreement on Trade in Services, Article XIV bis. The exception states that " Nothing in this Agreement shall be construed: (a) to require any Member [of the WTO] to furnish any information, the disclosure of which it considers contrary to its essential security interests; or (b) to prevent any Member from taking any action which it considers necessary for the protection of its essential security interests: (i) relating to the supply of services as carried out directly or indirectly for the purpose of provisioning a military establishment; (ii) relating to fissionable and fusionable materials or the materials from which they are derived; (iii) taken in time of war or other emergency in international relations; or (c) to prevent and Member from taking any action in pursuance of its obligations under the United Nations Charter for the maintenance of international peace and security." Ibid.

(222) DISCO II, par. 180. "The Commission will consider any such legitimate concerns as we undertake our own independent analysis of whether grant of a particular applications is in the public interest." Ibid., par. 179.

(223) Report on International Telecommunications Market Update 1999, prepared for Senator Ernest F. Hollings, Committee on Commerce, Science and Transportation, United States Senate, by the Federal Communications Commission, International Bureau, DA 00-87 (January 14, 2000) (1999 International Telecommunications Update), 15.

(224) Ibid.

(225) See, e.g., James M. Gifford, "Analysts Predict Industry Growth Via Internet," Space News, 4 December 2000, 8 (noting that because orbital positions from which satellites can serve customers are in short supply, the industry is likely to see "'quite a few partnerships blossoming' as companies work to secure more access to orbital parking spots for satellites").

(226) TMI Communications and Company, L.P., Order and Authorization, FCC 99-344 (November 30, 1999) (TMI Communications); In the Matter of New Skies Satellites, N.V. for Authorization to Access the U.S. Market, Order and Authorization, 14 FCC Rcd 13003 (1999) (New Skies).

(227) See, e.g., EUTELSAT Press Release, "Eutelsat Open for Business in the USA!," 2 February 2000. Retrieved January 11, 2001, from the World Wide Web: http://www.eutelsat.com.

(228) ING Barings, Satellite Communications, 13, supra n.45.

(229) Telesat Canada website, http://www.telesat.ca.

(230) "This Week in Brief," Space News, 22 May, 2000, 2. Retrieved January, 11, 2000, from the World Wide Web: http://www.spacenews.com.

(231) "South American Connection," Aviation Week & Space Technology, September 25, 2000, 23. Retrieved September, 29, 2000, from Lexis-Nexus, the World Wide Web: http://www.lexis-nexis.com.

(232) For more information regarding MCI's share in Embratel, see the MCI-Worldcom website, http://www.wcom.com/international/brazil.

(233) Theresa Foley, "Latin America: Satellites Add Spice to an Already Hot Market," Via Satellite, 14 June 2000, Vol. 15. No.6. Retrieved September 29, 2000, from the World Wide Web: http://www.lexis-nexis.com.

(234) "Embratel, France's SES to Build Satellites," Valor, 22 August, 2000. Retrieved January 11, 2001, from Foreign Broadcast Information Service (FBIS), FBIS-LAP20000822000064, the World Wide Web: http://www.199.221.15.211/.

(235) "Globalstar Do Brasil Signs Contract for Installation of Fixed Phones Aboard Inter-City Buses," Globalstar Press Release, 14 November 2000, http://www.globalstar.com.

(236) The Satmex website is: http://www.satmex.com.

(237) Ibid.

(238) "Plans for New Satellites Reported" Reformat, December 13, 2000, http://www.199.221.15.211. The Mexican government reportedly is to be granted 7% of Satmex VI's capacity for use in national security and social operations.

(239) Ibid.

(240) Geoffrey Cairn, "Wireless Networks: Excitement about MSS has Mostly Evaporated," Financial Times. Retrieved January 11, 2000 from the World Wide Web: http://www.ft.com/ftsurveys/sp7fa6.htm.

(241) "Andean Satellite Project Takes Off in Cartage," Santa Fe de Bogotá El Tempo, 9 June 1997. Retrieved January 11, 2001, from FBIS, FBIS-FTS19970610001291, the World Wide Web: http://www.199.221.15.211.

(242) PanAmSat also is participating in the development of a Network Access Point (NAP) of the Americas, which based in Miami, Florida, will link Internet Service Providers, Internet backbone providers, and other telecommunications services providers throughout the U.S., Latin America, Europe, and the Caribbean. PanAmSat Press Release, "PanAmSat Joins International Consortium to Develop New High Speed Exchange for Americas," 13 December 2000. Retrieved January 10, 2001, from the World Wide Web: http://www.panamsat.com/media.

(243) ORBCOMM website, http://www.orbcomm.com/newsroom/latestnews/colombia.htm. ORBCOMM Andes Carrie is owned by Virginia-based AES Corporation. It also has received operating licenses for ORBCOMM services in Venezuela, Panama and the Netherlands Antilles.

(244) "South American Connection," supra n.231.

(245) Theresa Foley, "Europe: The Continent Beckons," Via Satellite 10 September 2000, Vol. 15, No. 9. Retrieved September 29, 2000, from Lexis-Nexus, on the World Wide Web: http://www.lexis-nexis.com.

(246) Ibid.

(247) Ibid.

(248) EUTELSAT website, http://www.eutelsat.org/home.html.

(249) Foley "Europe: The Continent Beckons."

(250) EUTELSAT Press Release, "Eutelsat and the Italian Inter-University Consortium for Telecommunications to Provide a Tele-Education Network Using Ka-Band Frequencies and Bandwidth-On-Demand," 7 December 2000. Retrieved January, 10 2000, from the World Wide Web: http://www.eutelsat.com.

(251) "SATELLITE: Giant's footprint extends its mark," Financial Times Survey: Luxembourg 2000. Retrieved January, 11, 2001, from the World Wide Web: http://www.ft.com/ftsurveys/country/scf2fa.htm.See also "Astra 2D Blasts Off from Kourou," SES Astra Press Release, Betzdorf, Luxembourg, 19 December 2000. Retrieved January 10 2000, from the World Wide Web: http://www.ses-astra.com/corporate/press.

(252) Foley, "Europe: The Continent Beckons," supra n.245.

(253) Sylvia Dennis, "Alcatel, Loral in EuropeStar satellite joint venture 12/21/98," Newsbytes, 21 December, 1998. Retrieved January 11, 2001, from the World Wide Web: www.findarticles.com/m0HDN/1998_Dec_21/53455284/p1/article.html. Europe*Star activities are not isolated to Europe. The company has signed a deal to provide capacity for Sinhalese television broadcasts by the Sri Lankan telecom carrier Electroteks. See EuropeStar "Sri Lankan Programming to Broadcast Direct to Europe," Europe*Star Press Release, 21 December 2000. Retrieved January 10, 2001, from the World Wide Web: http://www.europestar.co.uk.

(254) Foley, "Europe: The Continent Beckons," supra n.245.

(255) Eurasiasat website, www.eurasiasat.com/index.htm. The Eurasiasat satellite was originally scheduled for launch on November 28, 2000, but was postponed four times. "Turkey Delays Launching of Turksat 2A Once Again Because of Bad Weather" Ankara Anatolia, 9 January, 2001. Retrieved 10 January, 2001, from FBIS, FBIS-GMP20010109000172, on the World Wide Web: http://199.221.15.211.

(256) Reportedly, less than 10% of Saudi Arabia is covered by cellular service. C.E. Unterberg, Towbin, "Hotbird," Vol. 3, No. 5, 23 October 2000, 26.

(257) Africa has only 14 million telephone lines for a population of 740 million people. Mark Turner, "Lagging in the Information Revolution: Africa" The Financial Times, 8 October 1999, 32. Retrieved October 3, 2000, from Lexis-Nexis, on World Wide Web: http://www.lexis-nexis.com.

(258) Michael Holman, "African Overview: Revolution Finally Gets Underway," The Financial Times, 17 March 1998, 5. Retrieved January 11, 2001, from Lexis-Nexis, the World Wide Web: http://www.lexis-nexis.com.

(259) Sara Frewen, "RASCOM releases satellite launch schedule," RCR Radio Communications Report, Vol. 19: 104, 28 February 2000. Retrieved October 3, 2000, from Lexis-Nexis, the World Wide Web: http://www.lexis-nexis.com.

(260) Ibid.

(261) "Nilesat 2 with Skyplex Gets the Go-Ahead," Interspace, No. 656, 18 November 1998. Retrieved October 3, 2000, from Lexis-Nexis, the World Wide Web: http://www.lexis-nexis.com.

(262) PanAmSat website, http://www.panamsat.com/comp/brochure2/africa/continent.

(263) Holman, supra n.258.

(264) Bruce S. Middleton, "The Asia-Pacific GEO Satellite Market Beginning the 21st Century," 3 (Paper released by the Pacific Telecommunications Council). Retrieved September 29, 2000, from www.ptc.org/planetptc/sessions/Wednesday/w31/w311. Until the financial crisis in the Asia-Pacific region in October 1997, the region led the world in the number of geosynchronous satellites launched during the 1990s. Market demand for satellites in Asia dropped sharply in 1998 and 1999 when the regional economic crisis peaked. For the first time in January 2000, the number of transponders in service in the Asia-Pacific was less than the number the prior year.

(265) Ibid, 5.

(266) Merrill Lynch, Satellite CEO Conference 2000, 9 February 2000,17.

(267) Ibid.

(268) Thuraya website, http://www.thuraya.com/corporate.htm. See also ING Barings, Satellite Communications, 103 supra n.45. AceS is jointly owned by PT Pasifik Satelit Nusantara (PSN) of Indonesia, Lockheed Martin Global Telecommunications (LMGT), the Philippine Long Distance Company (PLDT) and Jasmine International Public Company Ltd. of Thailand.

(269) Thuraya signed a deal with the Mauritanian-Tunisian Telecommunications Company (Matel) for Matel to act as Thuraya's service provider in Mauritania. Thuraya Press Release, "Matel Becomes Thuraya's Service Provider in Mauritania," 20 December 2000. Retrieved January 10, 2001, from the World Wide Web: http://www.thuraya.com/corporate.htm. See also ING Barings, Satellite Communications, 103, supra n.45.

(270) http://www.thuraya.com/corporate.htm, See also ING Barings, Satellite Communications, 103, supra n.45.

(271) Pasifik Satelit Nusantara website, http://www.psn.co.id/.

(272) "Broadband Services, Asiasat Stake Position SES as Global Player," Aviation Week and Space Technology, Vol. 150, No. 1, 4 (January 1999), 28. Retrieved September 29, 2000, from Lexis-Nexis, the World Wide Web: http://www.lexis-nexis.com. See also Aviation Week and Space Technology, "SES Takes on World from Tiny Luxembourg, Vol. 150, No. 14, 5 (April 1999), S6. Retrieved September 29, 2000, from Lexis-Nexis, the World Wide Web: http://www.lexis-nexis.com.

(273) Ibid.

(274) "Europestar to offer broadband services from Europe," Hindu Business Line, 18 August, 2000. Retrieved October 2, 2000, from the World Wide Web: http://www.hindubusinessline.com/2000/08/18/stories/151839rr.htm.

(275) Foley "Europe: The Continent Beckons," supra n.245.

(276) See, e.g., TMI Communications.

(277) Globalization Task Force Report, The President's National Security Telecommunications Advisory Committee (May 2000), ES-1. The "current regulatory structure effectively accommodated increasing levels of foreign ownership of United States telecommunications facilities, while allowing the Federal Government to retain authority to prevent any such foreign ownership that might compromise national security interests." Ibid.

(278) For example, in the case of the request of a Canadian company, TMI Communications and Company, L.P., to offer communications satellite services in the United States, including to the U.S. Government, the delay well-exceeded a year. TMI Communications, supra n. 226. "This [delay] prejudices ... the parties' interest in a full, fair and prompt resolution... . [C]ompetitors now have an incentive to ... slow down our approval. The resulting procedural morass undermines predictability and creates tremendous delays that deny American consumers' competitive service options... . The current process does not serve the parties or the American people well." TMI Communications, "Separate Statement of Commissioner Harold Furchtgott-Roth" (also raising questions regarding the proper branch of government with jurisdiction to enforce the agreements).

(279) Booz, Allen & Hamilton, 2000 Defense Industry Viewpoint, 19, supra n.36.

(280) Ibid.

(281) 1999 National Security Strategy: iii.

(282) Ibid., 12.

(283) For example, of the 150 countries participating in the 2000 World Radiocommunication Conference, 100 were part of the developing world. "Recommendations to Improve United States Participation in World Radiocommunication Conferences," Ambasssador Gail S. Schoettler, U.S. Head of Delegation, World Radiocommunication Conference 2000, 27 June 2000, 44. This report surmises that if there were a vote on an issue between developed countries and developing countries, "the developing countries would win it hands down." With respect to radio frequency spectrum, the report notes that usable radio spectrum is a global, public and scarce resource. We need the goodwill and partnership of all countries to share it." Ibid.

(284) The Cospas-Sarsat satellite system uses NOAA satellites and satellites from several other countries to detect and locate aviators, mariners, and land-based users in distress. The satellites relay distress signals from emergency beacons to a network of ground stations. Cospas-Sarsat began operating after a September 1982 aircraft accident in Canada in which three people were rescued. Since then, the system has been used for thousands of rescues worldwide.

(285) The main instruments aboard geosynchronous weather satellites are referred to as the imager and the sounder. The imager senses radiant and reflected energy from the earth's surface and atmosphere, while the sounder is able to determine the vertical temperatures associated with surface and cloud

temperatures and the ozone distribution. In addition to these sensors, other common instruments are search and rescue transponders, data collection and relay systems, and space environment monitors.

(286) The primary instrument aboard polar orbiting weather satellites is the Advanced Very High Resolution Radiometer (AVHRR). Data is transferred to the ground through the High Resolution Picture Transmission (HRPT). Image data is transferred through two AVHRR channels called Automatic Picture Transmission (APT).

(287) Jeremy Singer, "Lockheed, TRW Compete to Build NPOESS/Military-Civilian Weather System Could Top $1 Billion," Space News, 10 January 2000, 18.

(288) The U.S. National Weather Service is part of NOAA.

(289) Pirkko Saarikivi, et al., "Free Information Exchange and the Future of European Meteorology: A Private Sector Perspective," Bulletin of the American Meteorological Society, Vol. 81, May, 2000: 831-836. Retrieved October 23, 2000 from the World Wide Web: http://www.ametsoc.org.

(290) Weiss, Peter N. and Peter Backlund, International Information Policy in Conflict (paper submitted to the Harvard Information Infrastructure Project, 20 June 1996). Retrieved October 23, 2000, from the World Wide Web: http://www.ksg.harvard.edu.

(291) NOAA issued a solicitation for proposals in 1997 for technologies that could assist private companies in the development of space weather services. See http://ts.nist.gov.

(292) AccuWeather, like most value-added suppliers, applies computer programs to process raw data supplied by satellites, weather balloons and Doppler radar. The service can cost as much as $15,000 per month. Stephan Herrerra, "Weather Wise," Forbes Magazine, 14 June 1999. Retrieved October 23, 2000 from the World Wide Web: http://www.forbes.com/1999/0614/6312090a.html.

(293) Jerome Ellig, "Government and the Weather: The Privatization Option," The Federal Privatization Project, August 1989. Retrieved January 11, 2001, from the World Wide Web: http://www.rppi.org.

(294) Herrerra, supra n.292.

(295) "Satellites and Their Emerging Role in Commercial Ventures," (academic paper submitted by anonymous author) 17 April 1997. Retrieved October 23, 2000, from the World Wide Web: http://www.smgaels.org/physics/97/BKING.HTM.

(296) Ellig, 7.

(297) Ibid.

(298) http://www.esa.int/msg.

(299) "China Launches Weather Satellite," SpaceViews, 26 June 2000. Retrieved October 25, 2000, from the World Wide Web: http://www.spaceviews.com.

(300) Wei Long, "Chinese MetSat 'Sees' Heat and Moisture," SpaceDaily, 25 July 2000. Retrieved October 25, 2000, from the World Wide Web: http://www.spacer.com.

(301) U.S. Army Space Institute, Chapter 7, Section 5, U.S. Army Space Reference Text (U.S. Army Space Institute: Fort Leavenworth, KS, July, 1993). Retrieved January 11, 2001, from the World Wide Web: http://www.fas.org/spp/military/docops/army/ref_text/chap07e.htm.

(302) A history of INSAT, and other Indian space systems, is available at:http://www.bharat-rakshak.com/SPACE/space-satellite1.html.

(303) Pirko Saarikivi, et al.

(304) Ibid.

(305) Ibid.

(306) Ibid.

(307) Weiss and Backlund.

(308) Ibid.

(309) 1996 National Space Policy Fact Sheet, 2.

(310) An October 2000 Presidential Memorandum regarding spectrum for Third Generation (3G) Wireless Systems in the United States directs the Secretary of Commerce in cooperation with the Federal Communications Commission to work with government and industry representatives to develop plans to identify 3G spectrum and to make recommendations. "Memorandum for the Heads of Executive Departments and Agencies," The White House, 13 October 2000. The memorandum also provides that the Secretary of Defense, Secretary of Treasury, Secretary of Transportation, Secretary of State and the heads of any other executive department or agency that currently uses any of the 3G spectrum identified at the 2000 World Radiocommunication Conference to participate in the government-industry group. In addition, it directs the Department of State to present U.S. views to and coordinate with foreign governments and international bodies.

(311) For example, the 2000 World Radiocommunication Conference adopted a resolution instructing an organ of the ITU to study and consider possible draft recommendations linking the formal notification, coordination and registration procedures with ITU principles and regulations related to equitable access to spectrum and orbital resources. Under those principles and regulations, in the case of comparable requests for access to the spectrum/orbit resource by a country already having access to the orbit/spectrum resources and a developing country seeking it, the country having such access should take all practicable steps to enable the developing country to have equitable access to the requested orbit/spectrum resources. Provisional agenda items for the Spring 2001 Session of the Legal Subcommittee of the Committee on Peaceful Uses of Outer Space (COPUOS) are: the definition and delimitation of outer space, the character and utilization of the geosynchronous orbit, including consideration of ways and means to ensure the rational and equitable use of the geosynchronous orbit without prejudice to the role of the ITU. The continued international consideration and controversy regarding these spectrum-related issues underscores the importance of addressing them in the United States.

(312) To try to accommodate the high demand, regulators are devising spectrum sharing arrangements. Some observers have raised concerns that spectrum sharing may increase risk of service outages due to greater terrestrial interference. See Clayton Mowry, "Spectrum Sharing--Who Gets the Bigger Piece?," Via Satellite (January 2001), 16 ("spectrum-strapped regulators need to consider how satellites enable other technologies, provide high-quality competitive services and serve the public interest").

(313) 5 U.S.C. sec. 551-559.

(314) Various U.S. Government agencies and international organizations provide training and educational programs for foreign regulators. For example, the Federal Communications Commission's "International Visitors Program" annually provides tutorials and workshops to 400-500 visiting regulators representing approximately 100 countries. See http://www.fcc.gov/ib/ivp.

(315) Title III of the Communications Act of 1934.

(316) Evelyn Iritani and Peter Pae, " U.S. Satellite Industry Reeling Under New Export Controls," Los Angeles Times, 11 December 2000, 1 (citing Satellite Industry Association claim that since the new U.S. export restrictions took effect, the number of U.S.-manufactured spacecraft dropped). .

(317) Booz, Allen & Hamilton, 2000 Defense Industry Viewpoint, 13.

(318) Ibid.

(319) 1996 National Space Policy Fact Sheet, 2.

(320) Ibid.

(321) Ibid., 2.

(322) Tim Bonds et al., "Employing Commercial Satellite Communications, Wideband Investment Options for the Department of Defense," Project Air Force RAND (2000) (2000 RAND Employing Commercial Satellite Communications Study), 2-3 (study examines high bandwidth, minimally-protected satellite communications).

(323) Ibid.

(324) 2000 RAND Employing Commercial Satellite Communications Study, 19, supra n.322.

(325) See 1999 prepared Statement by Dr. John J. Hamre, 278, supra n.47.

(326) Ibid., 294.

(327) 2000 RAND Employing Commercial Satellite Communications Study, 19, n.19, supra n.322.

(328) "News Release," No. 729-00, Office of the Assistant Secretary of Defense, Department of Defense,6 December 2000. The Iridium system will address Navy requirements, which are "more than twice the current capability," as well as support Special Forces operations and combat research and rescue activities. The contract includes options, which if exercised, would extend the contract to December 2007, at an increased value of $252 million. The Department of Defense states that it entered this arrangement because "the Iridium system offers state-of-the art technology... on-satellite signal processing and inter-satellite crosslinks allowing satellite-mode service to any open area on earth ... mobile, cryptographically secure telephone service ... at substantially cheaper rates." The system also "'will enable real civil/military dual use, keep us closer to the leading edge technologically, and provide a real alternative for the future.'" Ibid.

(329) On December 15, 2000, Globalstar LP, filed a protest with the Government Accounting Office (GAO) alleging that the Department of Defense failed to seek an open competition prior to awarding the Iridium contract. GAO is scheduled to rule on the protest on March 26, 2001. Jeremy Singer, "DISA Is Confident Pentagon's Iridium Contract Will Hold," Space News, 8 January 2001, 4.

(330) 2000 RAND Employing Commercial Satellite Communications Study, 30 and n.13, supra n.322.

(331) See, e.g., 2000 NIMA Commission Report, supra n.125; Commercial SATCOM Advisory Group Findings &Recommendations, National Security Space Architect Briefing, 11-12 July 2000; 2000 RAND Employing Commercial Communications Satellite Study, supra n.322; "Prioritizing Army Space Needs, " Army Science Board Summer Study, Final Report (1999); "Commercial Space Opportunity Study," Final Report, Department of the Air Force, 16 February 2000. (CSOS Study); Jeremy Singer, "Navy Pushing Commercial Satellite Communications," Space News, 7 August 2000, 1; "Military Satcom: A Delicate Balance of Interests," Via Satellite, July 2000, S10 (Via Satellite Military Satcom).

(332) 2000 RAND Employing Commercial Satellite Communications Study, 5, supra n.322.

(333) Ibid.

(334) 2000 RAND Employing Commercial Satellite Communications Study, 18, supra n.322. See also Via Satellite Military Satcom, S10 (according to U.S. Space Command in 1998, "[a]round 60 percent of the military bandwidth we use today comes from the commercial sector"), supra n.331.

(335) Peter B. de Selding, "U.S., Britain Differ on Use of Satellite Vendors for Defense," Space News 4 December 2000, 4.

(336) 2000 RAND Employing Commercial Satellite Communications Study, 1, supra n.322.

(337) Ibid., xv.

(338) DISA does not operate space systems, but uses space systems to provide support.

(339) DISA currently has a multi-year contract with Lockheed Martin (formerly the COMSAT Corporation) called the "Managed Transponder Contract." That contract provides for annual leases of full transponders for world-wide, wideband commercial communications satellite services to the Department of Defense. DISA also has contract vehicles to meet short-term service needs and is expanding its commercial satellite service contracts. In addition, DISA evaluates commercial technologies and explores their applicability to follow-on Department of Defense satellites such as the Wideband Gapfiller Satellite.

(340) See, e.g., 2000 RAND Employing Commercial Satellite Communications Study, supra n.322; Army Science Board 1999 Summer Study, supra n.331; Via Satellite Military Satcom, S10, supra n.331.

(341) Jeremy Singer, "Navy Pushing Commercial Satellite Communications," Space News, 7 August 2000, 1.

(342) 2000 RAND Employing Commercial Satellite Communications Study, 6, supra n.322.

(343) Army Science Board 1999 Summer Study, 48. The study also recommends that "it is imperative that the Army establish a funded program designed to understand all aspects of the commercial space industry, to learn how to best translate military requirements into commercial capabilities, and to develop an optimal procurement model which points the most efficient way to acquire needed capability." Ibid.

(344) Sam Silverstein, "Globalstar Considers Mobile Gateways," Space News, 27 November 2000, 1. Reportedly, according to Globalstar, if developed, these advancements would enable phone calls and data transmissions to bypass the commercial earth stations (gateways) that link the satellite system with terrestrial telephone networks. Ibid.

(345) NIMA Commission Report, 60, supra n.125.

(346) FIA is the next complete constellation of imaging satellites distinguished by their greater numbers and larger pictures.

(347) NIMA Commission Report, 55-60, supra n.125.

(348) Army Science Board 1999 Summer Study, 48-49, supra n.331.

(349) Ibid.

(350) Daniel J. Boorstin, The Discoverers (Vintage Books 1983), 47.

PUBLIC SUBMISSION

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International Traffic in Arms: U.S. Munitions List Category XII; Revision

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Comment on DOS_FRDOC_0001-3226

Submitter Information

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Submitter's Representative: Jx3Corp, industries
Organization: Anonymous CyberDefense Communications, LLC
Government Agency Type: Foreign
Government Agency: Robert Peter Hannigan Director or the Government Communication Headquarters (GCHQ)

General Comment

2. Timing Services

The extremely accurate atomic timing clocks in the GPS satellites transmit information to any point in the world, twenty-four hours per day. GPS clocks provide ideal solutions to many of these synchronization requirements.(143) It is becoming less expensive for telecommunications companies to deploy GPS receivers to synchronize their network clocks rather than maintain a separate timing system, which is not likely to be as accurate. These applications are expected to increase as new information technologies are developed and introduced. The range of applications for GPS and its necessity in an increasingly information-technology dominated world are making GPS an indispensable part of the infrastructure of modern global societies. The GPS timing segment grew at a rate of 65% in 1997, compared to the 23% rate in the overall GPS market itself. (144)

The timing mechanism in the GPS system is critically important to a number of other technologies and services. For example, technologies for the electronic switching and transmission of voice, data and video require extremely accurate time synchronization. Broadcast radio and television and wide and local area networks require accurate time transfer.(145) Cellular telephones that operate on a time-based technology also rely on accurate timing. Financial banking and the growing e-commerce industry, require some form of accurate synchronization to certify the time of transactions. Network routers and switches require timing synchronization that GPS signals can provide. Wireless telecommunications data transfer requires an independent timing source so that signals are not lost or dropped because of electronic interference with system clocks of wireless stations.

3. Problems With The Satellite Configuration

Rotterdam-based Satellite Safe Ltd. serves corporate clients in Europe and South Africa by detecting viruses that can cause significant damage to corporate networks in Europe and South Africa and distributes anti-virus software over satellite.(208) "The only way to deliver this service when the Internet is blocked is from the air.'"

Hi,

Thank you for your time,

I am A PRIVATE ORGANIZATION as WELL as Munitions Exporter and he will be acting freely of my endeavor. However since these RF, RADIO, Satellite Waves are interfering with My own business I included him as a Private Organization As Well.

I as a "Private Cartel" - require my employees to sign a "Cartel Agreement" to do work for my Company Anonymous CyberDefense Communications, LLC so everything is kept private within my own Private Organization and Employees. People Share their Cookies, Their Data With Me and Their Tokens, Authorization Keys, Certificate Authorities, However, I Do not allow data sharing of any kind Digital or Analog with any, Educational, Governmental, Non-Governmental, Commercial, Non-Commercial, or Public or Private Entity.

Sincerely;
The Boss of North Carolina: Sebastciaun

The North Carolina Utilities Commission is an agency of the State of North Carolina created by the General Assembly to regulate the rates and services of all public utilities in North Carolina. It is the oldest regulatory body in state government. The present Commission evolved from the Railroad Commission which was created in 1891 and given authority to regulate railroad, steam boat, and telegraph companies.

Today, the Commission regulates electric, telephone (including payphone service and shared tenant service), natural gas, water, wastewater, water resale, household goods transportation, buses, brokers, and ferryboats. To a limited degree, the Commission regulates electric membership corporations, small power producers, and electric merchant plants. The Commission is also responsible for administering programs in North Carolina to ensure the safety of natural gas pipelines. The Commission does not regulate telephone membership corporations, cable TV, satellite, commercial mobile radio service, cellular, pagers, or data and internet service providers.

P.S. Rotterdam-based Satellite Safe Ltd. serves corporate clients in Europe and South Africa by detecting viruses that can cause significant damage to corporate networks in Europe and South Africa and distributes anti-virus software over satellite.(208) "The only way to deliver this service when the Internet is blocked is from the air.'"

Attachments

Commercial Space and United States National Security

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Comment on DOS_FRDOC_0001-3226

Submitter Information

Name: Jeremy Williams

General Comment

This is a direct violation of free speech. I do NOT support this change as it is a violation of the constitution.

Phoenix Engineering Inc.
3331 North Berkeley Lake Rd
Suite 100-110
Berkeley Lake, GA 30096
Ph (770) 364-7240
Fax (770) 783-8170

Dated: June 9th, 2015

Dr. Christopher Ralph Costanzo
Department of Commerce
Office of National Security and Technology Transfer Controls
Sensors and Aviation Division
14th and Pennsylvania Avenue NW
Washington, DC 20230

ITAR and the RAPTOR OWL VisSWIR Camera Range

The purpose of this letter is to explain why we believe that the above camera range should not be controlled under ITAR. The following information explains SWIR uses and list users in other parts of the world where ITAR is not an issue and highlights why having this camera on the United States Munitions List is not beneficial to the US. It also details how the OWL range of cameras and sensors was funded.

We understand the reason why it is important to ensure that certain items are controlled under the ITAR however we believe that this particular camera range should not be covered.

Fundamentally, there is no reason to have this specifically under ITAR control as the technology exists independently and is available from multiple vendors outside the US. It should be noted that the OWL range was developed 100% commercially with no US input or funding.

The OWL SW1.7 is a very well made, high sensitivity digital VIS-SWIR camera with various lens mount and control interface options. The OWL uses a 640 x 512 InGaAs sensor from SCD enabling high sensitivity imaging from 0.4μm to 1.7μm. The sensor has a 15μm x 15μm pixel with less than 50 electrons readout noise.

The majority of these cameras are outside the USA and are not under ITAR control. ITAR control of this product range has a negative impact on US Industry due to the fact that no such controls exist in any other county. Being controlled in this manner therefore places US companies at a distinct disadvantage to the rest of the world. It should be noted that this FPA technology is mainly developed outside the US (SCD, CHUNG WA etc) and placing this technology on the CML really places US developers at a distinct disadvantage.

ITAR control of this and related products stifles business, reduces revenue and, as a consequence, restricts private investment and puts the US behind in the technology race. The US ITAR control is ineffective if the objective is to limit access of this technology to other parts of the world - it's already there.

From a US perspective, foreign developers have less onerous controls placed on them and this attracts commercial US customers who want to work in international markets. The effect is that those US customers then become dependent on foreign development and the downward development spiral continues with the US falling behind in the technology race. Specialist products such as ours from the US are in most cases just ignored as an option due to: (a) the length time to get an export license (b) the amount of effort it takes and (c) the costs involved.

Worldwide, due to SWIR being under ITAR, US companies producing SWIR products are regarded as impossible to deal with.

Consider the list below. The rest of the world does not have the difficulties and overheads of ITAR control and contrast that against US companies that do have these issues. This list is only a snapshot. US businesses have both a business performance disadvantage due to the time licenses take and a financial disadvantage due to cost of operating the internal ITAR controls. They cannot realistically compete unless they operate a subsidiary outside the US. Clearly the control has little or no benefit and is hurting US based business and exporting jobs. We hope that you agree that I have presented a good argument to have the OWL640 SWIR family excluded from the ITAR list.

Examples of known Non-US SWIR (InGaAs) Commercial Developers:
CHUNG WA (15μm)
SCD (15μm)
HAMATSU (20μm)
XENICS (20μm)
SOFRADIR (15μm)
AIM (in development).

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The above either have better than 25μm x 25μm pixels or are suspected to have this in development.

Example Users:
Specim (Finland): food analysis, plastic recycling, mineral mapping for exploration in the mining, oil, gas and geothermal sectors
Machinex (Canada): Plastic recycling
Headwall (USA, Belgium): agriculture, monitoring crop vigour and disease treatment results in high-value crops
Gemalto (France): Quality control on their microchip
Daimler (Germany): automotive, adverse weather environmental sensing system
Google (USA): also looking at a similar application as Daimler
Apple (USA): and again, aiming to compete with Google and Daimler
Intel (USA, Israel): semiconductor inspection
Semilab (Hungary): Quality control on solar cell panel

The companies in the previous list highlighted in red are examples that have either opted to do the work outside the US or are being held back.

How it Affects Phoenix Engineering Inc.

In our case, we mostly use Raptor technology but in many cases we add value by making our own versions of the Raptor cameras to supply to our US customers. We provide high end product at an attractive price thus helping US industry. If it made sense we would move the manufacture of some of the Raptor COTS product to the US. While it is controlled under ITAR this is not practical.

Consider a complex industrial system that utilizes a SWIR camera manufactured in the USA by a US corporation. When there is an opportunity for the corporation to export their product there is a big problem. There are far reaching consequences of ITAR control. Even during development of a system there are the issues of managing the ITAR aspect of the product internal to the company such as the exclusion of non-residents. This is even before a company undertakes the very onerous and drawn out task of TRYING to obtain an export license. It is certainly not very helpful if they wish to sell competitively. Even selling within the US, US customers shy away from buying ITAR controlled items due to the overheads attached.

How this all began.

With a potential to reduce the cost of SWIR camera manufacture SWIR became of great interest. We saw this having dual use with obvious industrial uses.

Raptor, encouraged by Phoenix Engineering, embarked on the SWIR 640 project after being approached by SCD (Israel) who expressed an interest in getting into the market around November 2011. The reason SCD were interested is that they saw this as a relatively easy development as the 640 x 512 ROIC (Read Out Integrated Circuit), the CMOS part of the sensor, was already developed as an internal R&D project for their own InSb program. So substituting InGaAs for the InSb to make it sensitive to the SWIR band only looked like a material change with some packaging and handling issues. Raptor expressed an interest as we saw the possibility of making a good camera for use in EU, North America and the other NATO based countries that the UK government and Israel allows us to ship to. With this in mind, Raptor paid for the packaging development within SCD without any help from any company or organization or government program. This cost Raptor approximately $1M for the package change to SCD and was agreed around June 2013. It also cost Raptor approximately $400,000 additional internal NRE to get the camera to market. Raptor does not have exclusivity – SCD sell this sensor throughout the world. Raptor continued to work closely with SCD, specifically in packaging and testing.

Un-Equal Playing Field

As for restrictions in shipping, Raptor is governed by the UK government that strictly enforces the shipments by regular auditing of Raptor. The commodity code that Raptor use is 9006 3000 00 for SWIR cameras (and EMCCD cameras). An extract of this classification is below from an internal document where we reviewed other possible codes such as 8525 8019, etc.

This is a much more realistic approach to the control of this technology. The result is that the UK and the rest of Europe can target US companies while it is almost impossible, due to ITAR, for the US to target the EU and the rest of the world competitively. The section in blue below details the UK Government Classification that covers the OWL cameras.

1.1.1 UK Government 9006 3000

Section XVIII
Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof
90
Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof
06

Photographic (other than cinematographic) cameras; photographic flashlight apparatus and flashbulbs other than discharge lamps of heading 8539

The number following each commodity's *Description* is its *Commodity code*
Cameras of a kind used for preparing printing plates or cylinders 90 06 100000
Cameras specially designed for underwater use, for aerial survey or for medical or surgical examination of internal organs; comparison cameras for forensic or criminological purposes 90 06 300000
Instant print cameras 90 06 400000
Other cameras
With a through-the-lens viewfinder (single lens reflex (SLR)), for roll film of a width not exceeding 35 mm 90 06 510000
Other, for roll film of a width less than 35 mm 90 06 520000
Other, for roll film of a width of 35 mm
Disposable cameras 90 06 531000
Other 90 06 538000
Other 90 06 590000
Photographic flashlight apparatus and flashbulbs
Discharge lamp (electronic) flashlight apparatus 90 06 610000Other 90 06 690000
Parts and accessories
For cameras 90 06 910000
Other 90 06 990000

Also of note, as the product is Israeli in origin, we are bound by an agreement with SCD with regards to exporting the SWIR 640 camera and any derivative that uses this sensor. The agreement specifically is:-

*In any case, these components ordered from SCD - SemiConductor Devices shall not be re-exported as is or after integration into **Raptor Photonics Limited** products to the following countries:*
a. Belorussia, Bolivia, China, Cuba, Eritrea, Iran, Lebanon, Libya, Malaysia, Myanmar, Nicaragua, North Korea, Pakistan, Russia, Somalia, Sudan, Syria, Venezuela, Yemen and Zimbabwe
b. Countries under UNSC or EU embargo or restrictions

Most countries have similar restrictions to the UK restrictions. The SCD agreement is even more stringent.
As sales began the use was heavily scientific. As for the first non scientific customers, these were surveillance applications such as cameras in Wescam airborne gimbals – customers include UK coastguard, UK Navy, US Navy, etc.

The newer variation of the Owl 640 camera called the "Ninox " is used almost exclusively for scientific applications. The Ninox is larger with more thermal considerations incorporated in the design, allowing it to cool to lower temperatures resulting in a more sensitive camera. Some current applications for OWL cameras are things like detecting skin defects and recycling (hyper spectral imaging to identify different types of plastics).

Summary

I am sure that when considering the facts I have laid out above you will understand our position regarding the situation. ITAR control of the OWL range provides minimal protection at best. I believe that it does nothing positive for the security of the USA and places US industry at a competitive disadvantage. This technology is being developed in many parts of the world and being used extensively in scientific and industrial environments. It is relatively easily accessible in other parts of the world.

I recommend that the proposed language in Category XII be removed for the time being and the original language retained. Furthermore, I respectfully request that for the next draft, the issue of dual use and world-wide use of SWIR be fully investigated so that scientific and industrial organizations within the USA are not burdened with rules that are solely applicable in the USA that make the USA uncompetitive in a world-wide context with regard to the utilization of this technology.

Regards,

John Craigie
Vice – President and Co Founder
Phoenix Engineering Inc.

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Phoenix Engineering Incorporated is a Woman Owned Small Business Registered in Georgia

6/17/2015

Subject: Response to Proposed Rule: Amendment to the ITAR: Revision of U.S. Munitions List Category XII

From:
Dr. Jonathan S. Kane,
Chief Technology Officer
Clear Align, LLC
Jon.kane@clearalign.com
603-889-2116 x224

Clear Align is a supplier of high precision optical assemblies in the Visible, SWIR, MWIR and LWIR including components, fixed focal length lenses and zoom lenses. It is also the owner of “irZoom” one of the world’s leading companies in infrared zoom lenses. More information can be found on our websites, www.clearalign.com and www.irZoom.com .

This response is a public response for the proposed EAR Regulations: Control of Fire Control, Range Finder, Optical and Guidance and Control Equipment proposed by the Industry and Security Bureau on 5/05/2015.

This comments concerns itself with **Paragraph (C)(16)(iii) and (C)(16)(iv)**

1 PARAGRAPH XII(C)(16)(III)

1.1 Discussion of the Rule

The rules states that Fixed-Site Reconnaissance, surveillance or perimeter security systems or equipment having greater than 640 detector element in any dimension are to be controlled under the ITAR.

1.2 Our comment to the rule

This rule seeks to control high definition cameras used for reconnaissance, surveillance or perimeter security. In today’s world these are no longer just functions of the military but are routinely used by police forces, fire fighters, and port security worldwide. This means that this application is by it’s very nature dual use and should be rightly controlled by the DOC bookend and not by the ITAR.

Implementation of this rule means that our lens systems that have been determined under Commodity Jurisdiction to be controlled under DOC would now come under the Purview of DOS.

The monetary cost to us will be significant as once a lens is deemed ITAR except when it is "specially designed" in the general market, a non-US lens is always chosen. We have never won a sale in the last 10 years in a commercial run-off when our lenses are deemed ITAR.

There is significant foreign availability of infrared lenses with vendors from China, Singapore, Japan, Israel, Germany, England, and France. With all of this competition limiting ourselves to this restriction is destructive to commerce while not increasing the security of the United States.

Sopme Examples

http://www.wavelength-tech.com/

http://temmek.com/

http://www.rp-optical-lab.com/

http://www.ophiropt.com/infrared-optics/infrared-optics-home

http://www.angenieux.com/Angenews/en11-12/files/assets/basic-html/page13.html
http://ulooptics.com/infrared-optics

1.3 Requested action

We request that the government delete paragraph (C)(16)(iii) due to the dual use paradigm and foreign availability. We do understand that control may be warranted but if so, we request that it at least be moved off the ITAR and onto the EAR bookend.

2 RULE (C)(16)(IV)

2.1 Discussion of the Rule

The rule states that combat vehicles, tactical wheeled vehicles, naval vessel, or aircraft pilotage systems or equipment having a variable field of view or field of regard (e.g. electronic pan or tilt) and either an IRFPA article controlled in this subchapter with greater than 640 detector elements in any dimension.

2.2 Our Comment to the rule

Another way of saying "variable field of view" is "Zoom Lens".

Since our company has a division called "IrZoom" this directly targets all of our future products for high definition cameras such as the MirZ 1522HD, Mirz 3022HD, MirZ 4022HD, LirZ 33/99HD, LirZ 206HD. So while this does not affect our current line of lenses in about 1 year it will act to stymie our growth.

Zoom Lenses have significant foreign availability with suppliers from Singapore, China, France, Japan, Israel and Germany.

http://www.wavelength-tech.com/

http://temmek.com/

http://www.rp-optical-lab.com/

http://www.ophiropt.com/infrared-optics/infrared-optics-home

http://www.angenieux.com/Angenews/en11-12/files/assets/basic-html/page13.html
http://ulooptics.com/infrared-optics

In order to compete on technology and not just on price we must continue to advance the state of the art for lens systems. One obvious step in the market is high definition lenses to match the newer cameras and everyone in this market will eventually be forced to move to the higher definition formats.

This means that our lenses will be captured while international competition will not be forced to do so as several of the competitors countries are not signers to the Wassenar agreement. This creates a situation on the ground where we predict at least a 90% loss rate due to ITAR for our new equipment restricting us to just the United States market. There is presently much less domestic funding of this type of research and so by regulatory design we will be disadvantaged.

2.2.1 Requested Action

We request that (C)(16)(IV) be rewritten as follows:

Combat Vehicle, Tactical wheeled Vehicle, naval vessel, or aircraft pilotage systems having electronic pan or tilt and either an IRFPA article controlled in this subchapter with greater than 640 detector elements in any dimension or an IIT controlled in this category (e.g, DAS, DVE, SeaFLIR, PNVS);

Note to paragraph (c)(16)(iv): This paragraph does not control distributed aperture sensors specially designed for civil automotive lane departure warning or collision avoidance.

From:	Kojima, Jun J. (GRC-LTC0)[OHIO AEROSPACE INSTITUTE]
To:	DDTCPublicComments
Subject:	ITAR Amendment‹Category XII.
Date:	Monday, July 06, 2015 3:09:25 PM

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

I am a scientist who provides combustion research to NASA Glenn Research Center, Cleveland, OH.
I appreciate the opportunity to comment on the proposed changes to the USML.

Our laboratory uses image intensified CCDs (ICCDs) and electron multiplying CCDs (EMCCDs) for propulsion and fuel researches. This equipment are essential diagnostic tools for advanced combustion experiments and measurements. Without these cameras our cutting edge scientific projects will suffer greatly as there is no alternative to these equipment for sensitive optical sensing.

As a whole, Ohio Aerospace Institute is very hesitant to purchase any ITAR restricted items as restricting their access to foreign graduate students is onerous. As a Principal Investigator, it would be impossible for me to justify the purchase of a scientific tool that could not be used by many of my students.

It would be especially devastating for the photonics research community if the US government were to place ITAR restrictions on scientific grade cameras, such as intensifier CCD, near infrared InGaAs and EMCCD cameras. If this were to happen, it will setback US research significantly, especially, in contrast to the research in EU and Asia have no such restrictions exist from their respective Governments.

If you require any further information, please contact me at 440.962.3095 or via email at JunKojima@oai.org.

Sincerely,

Jun Kojima, Ph.D.
Principal Scientist

Ohio Aerospace Institute

communications

International Licensing Group
201 12th Street South, Suite 800
Arlington, Virginia 22202
Phone: 703-412-7194 Fax: 703-416-1074

6 July 2015

U.S. Department of State
Office of Defense Trade Controls Policy
PM/DTCC, SA-1, Room L132
2401 E St., NW
Washington, D.C. 20522

Attention: Mr. Peartree, Director

Subject: ITAR Amendment – Category XII

Enclosure: Comments & Recommendations for Proposed Category XII

Dear Mr. Peartree,

Upon review, L-3 has determined that the proposed rule change would have a devastating effect to our focal plane array business as well as the business of our U.S. focal plane array customers. The additional requirements for licensing of 9 Hz products and the removal of license exceptions for Strategic Trade Authorization (STA) countries and Canada will be extremely harmful to the U.S. industrial base and may drive some companies out of the business entirely. An export control philosophy consistent with the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies* and the *Wassenaar Arrangement Munitions List* would create a level playing field for L-3 with our competitor's resident in participating countries. If the proposed rule change becomes law, L-3 fears the U.S. industrial base may be eroded to the point where it becomes noncompetitive and unable to provide leading edge solutions for the U.S. warfighter.

Additionally, L-3 fears that the proposed changes to the ITAR and EAR could impact U.S. companies' ability to successfully compete. Our assessment is that the proposed rules create an environment in which U.S. Companies cannot successfully compete internationally. This concern is based on the following:

- Many of the proposed changes are viewed as overly restrictive and not consistent with availability from multiple sources of foreign supplies.
- As currently written the classification criteria are complex and difficult to interpret and the "Bright Line" of demarcation between USML and the CCL is not evident. This will require a great deal of effort from both technical and non-technical resources to appropriately determine classifications and subsequent export management. This will affect cost and schedule competitiveness directly and indirectly.

In conclusion, the changes to the ITAR and the EAR do not appear to be meeting many of the objectives of the ECR. L-3 believes that the following suggestions should be taken into consideration:

- A rewrite of the guidelines with increased clarity of classifications and motivations would be extremely beneficial.
- Specially designed should be applied more broadly to this Category, as opposed to performance parameters that are not militarily significant or significantly lower than foreign sources of supply.
- The establishment of the "Bright Line" between the USML and the CCL, and the CCL and the new 600 series entries is questionable. Determining which items are controlled by category XII versus CCL is convoluted.
- In the product areas of FPAs, several parameters that result in control coverage appear too restrictive and not militarily significant.
- Multiple dual-use examples have been found that meet or exceed the Category XII and CCL control criteria.
- Multiple examples of foreign availability have been found that provide products that meet and exceed the proposed Category XII and CCL controls.
- Consideration should be given to utilizing the current Category XII wording with the "specially designed" criteria applied.

Sincerely,

William O. Wade
Vice President
International Licensing & Compliance
L-3 Communications Corporation

Enclosure: As Stated

ITAR Amendment – Category XII

In response to the Department of State's proposed changes to the ITAR to revise Category XII, an internal technical review was conducted resulting in several key technical conclusions, with supporting discussion and comments provided in following sections. The technical review emphasized evaluation of the thermal imaging systems, sub-systems, and components.

Comparison Summary Tables for Discussion

A subset of our interpretation of the currently proposed regulations indicates IRFPAs, Camera cores, and imaging systems related to our product lines of interest are controlled under Category XII(c) and CCL ECCNs as summarized in the following tables:

Category XII *(c) IR FPAs, Cameras & Systems (IRFPAs)						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	Notes
not given	not given	900	30000	N	2	Stand-alone FPA
1	640	900	30000	Y	3	Stand-alone FPA
2	256	900	30000	Y	4	Stand-alone FPA

Table 1: Category XII IRFPA Related Component Summary

Category XII *(c) IR FPAs, Cameras & Systems (Camera Cores/kits)						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	Notes
1	640	900	2500	N	12-v	IR Camera Core/kit
2	111,000	900	30000	Y/N	12-viii	IR Camera Core/kit
1 or 2	256	2500	30000	N	12-vi	IR Camera Core/kit
2	not given	2500	30000	Y	12-ix	IR Camera Core/kit

Table 2: Category XII IRFPA Related Camera Cores/Kits Summary

Category XII *(c) IR FPAs, Cameras & Systems (Imaging Systems)						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	Notes
any	> 640	As defined in C		As defined in C	16-iii & 16-iv	Imaging systems

Table 3: Category XII IRFPA Related Imaging Systems Summary

Category XII *(c) IR FPAs, Cameras & Systems (Multi-spectral IRFPAs)						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	Notes
not-given	not-given	1500	30000	Y	6	

Table 4: Category XII Multi-Spectral FPA Related Summary

ECCN 6A002 (Optical Sensors, Equipment, and Components))						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	Notes
2-D	not given	1200	30000	Y	a.3.c	Encapsulated FPA
1-D	not given	3000	30000	y	a.3.e	Encapsulated FPA
not given	not given	400	30000	Y	Note	Existing CCL

Table 5: CCL ECCN 6A002 IRFPA Related Component Summary

ECCN 6A615 (New Series)						
FPA Dimension	# of elements	Low Cut-off (nm)	High Cut-off(nm)	Encapsulated	para #	
not given	640	not given	not given	Y	g	Combat vehicle

Table 6: CCL ECCN IRFPA Related Parts, Components, and Accessories.

Comments & Recommendations

1. It appears that Table 1, entry 1 overlaps with Table 2, entry 1? 900nm to 2500nm is a subset of 900nm to 30000nm. Is this strictly a component vs. camera core distinction?

2. What is the significance of the 2500nm long-cut-off for Table 2, entry 1?

3. Table 1, entries 2 and 3 appear to overlap yet conflict with Table 5, entries 1 and 2, CCL ECCN 6A002.a.3.c and a.3.e respectively.

- The CCL ECCNs are a sub-spectrum of Category XII as written due to longer short-end spectral cut-off, yet they have no limitation on element count as provided by Table 1.

4. It appears that Table 2, entry 3 has overlap with Table 1, entry 1?

- 2500nm to 30000nm is a subset of 900nm to 30000nm, is this the motivation for the 256 total element count allowed in Table 2, entry 3 vs. none specified in Table 1, entry 1? Or is this relaxation due to a higher level of assembly?

5. It appears that Table 2, entry 4 could be in conflict with Table 1, entry 3.

- 2500nm to 30000nm is a subset of 900nm to 30000nm, is this the motivation for no limit on detector element count? Or is this relaxation due to a higher level of assembly?

6. How does Table 3, entry 1 align with CCL ECCN 6A615, Table 6, entry 1?

- Category XII control of "combat vehicle infrared imaging systems with greater than 640 elements in either dimension" with no spectral information provided, while ECCN 6A615(g) states control for combat vehicle with an IRFPA with LESS than 640 elements with no dimensionality or spectral region provided.

7. Does this indicate only those camera cores listed in table 2, entry 4 are allowed for such systems?

8. How does this relate to Category XII(c)(16)(iii) for fixed surveillance nodes?

9. What is the rationale for the Category XII 1500nm low spectral cut-off for multi-spectral sensors, vs. the Category XII 900nm cut-off, and the CCL low cut-offs in Table 5?

10. How do the Table 5 entries align to those of Table 1, entries 2 and 3?

11. Is the relaxation to no limitation on element number due the difference in spectral response?

12. Assessment and recommendations on the appropriateness of the parameters and thresholds chosen to designate IRFPAs sensors, and systems. Our key observations based on our assessment of the classification parameters and thresholds criteria from category XII is as follows:

- The motivation for the choice of IR based imaging technology classification based on spectral regions, detector count, encapsulation, and integration levels is not clear
  - For example the inclusion or exclusion of specific known operational laser wavelengths does not seem to be apparent.
  - It is apparent that some control relaxation is intended when transitioning from component, to camera core, to imaging system.

Recommendation(s):

- Capture proposed classifications in a matrix format and/or flowchart to aid in interpretation.
- Clarify distinction between ITAR and EAR IRFPA classification criteria as well as intent.

13. Paragraph: Cat XII(a)(2)(i)

- **Issue**: Some thermal weapon sights are commonly used in commercial applications and this proposed rule would now require an ITAR license for export. Items similar to the one below are widely used for hunting.

Thermal weapons sight affected by this proposed rule change			
Company	**Country**	**Description**	**URL**
Torrey Pines Logic	USA	T10 thermal weapons sight, 80x60 FLIR Lepton	http://tplogic.com/thermal-solutions/t10/

Recommendation: Revise the proposed rule to:

(2) Weapon sights, weapon aiming systems or equipment, and weapon imaging systems or equipment (*e.g.,* clip-on), with or without an integrated viewer,

display, or reticle, and incorporating **and** specially designed to incorporate any of the following:

(i) An infrared focal plane array having a peak response at a wavelength exceeding 1,000 nm;

(ii) An article subject to this subchapter; or

(iii) A ballistic computer for adjusting the aim point display;

14. Paragraph: XII(c)(2)

- **Issue**: Microbolometer infrared arrays are dual-use and commonly used in commercial applications including automotive imaging, cell phone cameras, surveillance, thermography, fire fighting, home inspection, utility inspection, scientific research, and unmanned aerial vehicles. These devices are listed on the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies* (6.A.2.a.3.f) and not on the *Wassenaar Arrangement Munitions List*. Listing dual-use items on the USML results in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices or the President's Export Control Reform Initiative. High performance microbolometer infrared arrays are available from foreign sources including China.

Commercially available uncooled microbolometers are available from sources worldwide including those in mainland China, Korea, Japan, Europe, and Israel as listed in the following table.

Cat XII(c)(2) Thermal Focal Plane Arrays			
Company	**Country**	**Description**	**URL**
DALI Tech	China	640x480, 17 µm	http://www.dali-tech.us/
IRay Technology	China	640x512, 20 µm	http://www.ecvv.com/company/iraytekblake/index.html
Guide Infrared	China	400x300, 25 µm	http://www.guide-infrared.com/main.aspx?lang=en
GWIC	China	640x512, 20 µm	http://www.gwic.com.cn/en_index.html
i3 Systems	Korea	384x288, 17 µm, 640x480, 17 µm	http://www.i3system.com/eng/n_product/product101.html
NEC	Japan	640x480, 12 µm	http://techon.nikkeibp.co.jp/english/NEWS_EN/20121206/255011/
ULIS	France	80x80, 384x288, 640x480, 1024x768	http://www.ulis-ir.com/
Sensonor	Norway	384x288, 25 µm	http://www.sensonor.com/

Fraunhofer IMS	Germany	320x240, 640x480, 17 μm	http://www.ims.fraunhofer.de/en/homepage.html
SCD	Israel	384x288, 640x480, 1024x768	http://www.scdusa-ir.com/
L-3	US	320x240, 640x480, 1024x768	http://www2.l-3com.com/irp/products/imaging.htm
Seek	US	206x156, 12 μm	http://www.thermal.com/
FLIR	US	80x60, 160x120, 320x240, 640x480	http://www.flir.com/
DRS	US	320x240, 640x480, 1024x768	http://www.drs.com/products/rsta/tamarisk.aspx
BAE Systems	US	320x240, 640x480	http://www.baesystems.com/product/BAES_020547/mim500/

Recommendation: Move all Permanently Encapsulated Sensor Array infrared microbolometer components to the Commerce Control List. Use the *Wassenaar Arrangement Munitions List* as a guide for ITAR.

15. The limitations to greater than 256 elements for an encapsulated IRFPA component and a camera-core with > 111,000 elements is overly restrictive as indicated in Table 1, entry 3 and Table 2, entry 2.

- As written this is 256 total elements for the 2-D IRFPA component. This is equivalent to a 16x16 element detector which is nowhere near the state-of-the-art technology
- As written this 111,000 element count would accommodate a 333 x 333 element array which is nowhere near the state-of the art technology.
- Numerous dual-use products and foreign sources of supply use FPAs that far exceed 256, or 111,000 for camera-cores, as well as dual band sensors. At present 640 x 512 or 480 element format detectors are a standard format. For example:
    - Selex (UK): http://www.selex-es.com/product-portfolio/optronics-system/thermal-detectors
    - Sofradir (France): http://www.sofradir-ec.com/products-cooled.asp
    - Zeiss/Cassidian (Germany): http://bbmsolution.com/wp-content/uploads/2014/09/Prosp8_Sensors_WEB.pdf
    - AIM (Germany): http://www.aim-ir.com/en/main/products.html
    - Xenics (Belgium): http://www.xenics.com/en

Recommendation(s):

- Adjust classification parameters to be consistent with foreign sources of supply
- Choose classification parameters based on military significance or agreed upon specially designed criteria

16. Establishing control based only on element count has questionable military significance.

- Pixel element count, pitch, well depth, quantum efficiency, thermal performance, noise properties, and system implementation combine to produce key potential discriminators which are resolution and sensitivity at the imaging system level. Additional militarily significant features would include ruggedized packaging, environmental operation range, robust software, and weapons mounting capability.

Recommendation: Choose classification parameters based on military significance or agreed upon specially designed criteria

17. The encapsulated assembly definition may not be appropriately defined.

- The encapsulated assembly when outfitted with an appropriate bandpass filter could influence the spectral bandpass of the sensor assembly, as a subset to the actual IRFPA spectral response. This would allow alleviation of strict controls on items that are ultimately used for only a subset of the IRFPA response spectrum.

Recommendation: Consider broadening the definition of the encapsulated assembly to align with the intent of component definition.

18. Paragraph: XII(c)(5)

- **Issue:** The use of array size to identify those encapsulated microbolometer IRFPAs that are for military use is not appropriate. Encapsulated microbolometer IRFPAs having more than 328,000 detector elements are dual-use and commonly used in commercial applications. Commercial applications include: surveillance, utility inspection, scientific research, and unmanned aerial vehicles. Constraining the array size has no specific military significance. These devices are listed on the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies* (6.A.2.a.3.f) and not on the *Wassenaar Arrangement Munitions List.* Listing dual-use items on the USML results in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices or the President's Export Control Reform Initiative.

- Microbolometer infrared arrays with a pixel count above 328,000 are available from foreign sources, for example:
  a. ULIS PICO-1024 (http://www.ulis-ir.com/index.php?infrared-detector=gen2pico1024)
  b. SCD Bird-XGA (http://www.scd.co.il/Bird-XGA-17)

Recommendation: Move all Permanently Encapsulated Sensor Array infrared microbolometer components to the Commerce Control List. Use the *Wassenaar Arrangement Munitions List* as a guide for ITAR.

19. Category XII(c)(9) and (e)(7), control IDCA parts and components in an overly restricted manner.

- Control parameters are defined as follows:
- Cryo-coolers having a cooling source temperature below 218K and an MTTF in excess of 3000 hours
- Active cold fingers
- Variable or dual aperture mechanisms
- Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category
- Numerous foreign sources of supply are providing cryo-coolers with a cooling source temperature below 218K. This is far from the state of the art for this technology
- The MTTF of 3000 hours is approximately a factor of ten lower than state of the art components
- This item is listed on the Wassenaar Sensitive List of Dual Technologies, but with an MTTF of 2500 hours. A 500 hour discrimination between USML and Dual-use appears trivial and is likely difficult to verify
- Discrimination based on the use of a cold-finger is questionable as this is a standard method of implementation

Recommendation(s):

- Adjust classification parameters to be consistent with foreign sources of supply.
- Choose classification parameters based on military significance or agreed upon specially designed criteria.

20. Paragraph: XII(c)(12)

- **Issue**: The proposed rule places all camera cores with greater than 328,000 (640x512) pixels on the USML. It also places cores with greater than 111,000 (384x288) pixels that are able to sustain a threshold weapon shock on the USML.

- The use of array size to identify microbolometer infrared camera cores manufactured for military use is not appropriate.
- Microbolometer camera cores having more than 328,000 detector elements are dual-use and commonly used in commercial applications. Microbolometer infrared camera cores are used for many high volume applications and there has been a rapid rise and acceptance of uncooled bolometer technology in commercial applications such as automotive and mobile phone cameras.
- Additional commercial applications include: surveillance, utility inspection, scientific research, and unmanned aerial vehicles. Constraining the array size has no specific military significance. These devices are listed on the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies* (*6.A.3.b.4.b*) and not on the *Wassenaar Arrangement Munitions List*. Listing dual-use items on the USML results in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices or the President's Export Control Reform Initiative.
- Commercially available uncooled microbolometer camera cores able to function after weapon shock with greater than 111,000 detector elements and cores with pixel count greater than 328,000 are available from sources worldwide including those in Europe and Israel as listed in the following table.

Cat XII(c)(12) Microbolometer camera cores affected by this rule change			
Company	**Country**	**Description**	**URL**
ULIS	France	640x480, 1024x768	http://www.ulis-ir.com/
SCD	Israel	640x480, 1024x768	http://www.scdusa-ir.com/
i3 Systems	Korea	640x480, 17 μm	http://www.i3system.com/eng/n_product/product101.html
FLIR	US	ONE, Lepton, Tau, Quark	http://www.flir.com/
FLIR/ Autoliv	US	Automotive	http://www.caranddriver.com/comparisons/night-vision-systems-compared-bmw-vs-mercedes-benz-vs-audi-comparison-test
DRS	US	Tamarisk 640x480, Tamarisk 1024x768	http://www.drs.com/products/rsta/tamarisk.aspx
BAE Systems	US	640x480	http://www.baesystems.com/product/BAES_020547/mim500/
L-3	US	NanoCore640, NanoCore1024	http://www2.l-3com.com/irp/products/imaging.htm

DRS	US	640x480, 1024x768	http://www.drs.com/products/rsta/tamarisk.aspx

Recommendation: Move all infrared microbolometer camera cores to the Commerce Control List.

21. Paragraph: XII(c)(16)(iii)

- **Issue:** This proposed rule places fixed-site reconnaissance, surveillance or perimeter security systems or equipment using IR focal plane arrays with greater than 640 elements in any dimension on the USML.

- The use of array size to identify microbolometer infrared camera cores manufactured for military use is not appropriate. Microbolometer camera cores having more than 640 detector elements in any dimension are dual-use and commonly used in commercial applications. Furthermore, surveillance and perimeter security are inherently commercial applications. Constraining the array size has no specific military significance. Cameras containing IR focal plane arrays with more than 640 elements in any dimension are listed on the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies (6.A.3.b.4.b)* and not on the *Wassenaar Arrangement Munitions List.* Listing dual-use items on the USML results in unilateral control of US-made devices and is not consistent with the intent of the Wassenaar Agreement for export controlled devices or the President's Export Control Reform Initiative.

- Commercially available uncooled microbolometer camera cores with pixel count greater than 640 in any dimension are available from sources worldwide including those in Europe and Israel as listed in the following table.

Cat XII(c)(16) Surveillance microbolometer camera cores affected by this rule change			
Company	**Country**	**Description**	**URL**
ULIS	France	Pico-1024	http://www.ulis-ir.com/
SCD	Israel	Bird-XGA (1024x768)	http://www.scdusa-ir.com/
DRS	US	Tamarisk 1024x768	http://www.drs.com/products/rsta/tamarisk.aspx
L-3	US	NanoCore1024	http://www2.l-3com.com/irp/products/imaging.htm

Recommendation: Move all infrared microbolometer cameras and camera cores to the Commerce Control List. Use the *Wassenaar Arrangement Munitions List* as a guide for ITAR.

22. Category XII(f) is stated as;

a. **(f) Technical data (as defined in 120.10 of this subchapter) and defense services directly related to the defense articles enumerated in paragraphs (a) through (e) of this category. (See 125.4 of this subchapter for exemptions.)(MT for technical data and defense services related to articles designated as such.)*

Based on the asterisk, technical data is considered Significant Military Equipment.

a. Designating all technical data directly related to Category XII defense articles will create a significant issue because industry will need DSP-83s to submit marketing licenses. This has never been done before (except for technical data directly related to manufacture and production).
b. The notes to paragraph (f) are confusing. If the point is to "clarify" that technical data related to an ITAR component is ITAR controlled even if the ITAR component is incorporated in an EAR controlled end item, then the notes are not necessary. The additional explanation makes this more confusing and appears to create contradictions.
c. The notes should not be used to clarify what is considered technical data. Technical data is defined in 120.10. Attempting to explain in a note to a note of a subparagraph is not recommended.

Recommendation: Remove the asterisk and use the following language:

"(f) Technical data (as defined in §120.10) and defense services (as defined in §120.9) directly related to the defense articles described in paragraphs (a) through (e) of this category. (See §125.4 for exemptions.) Technical data directly related to manufacture and production of any defense articles described elsewhere in this category that are designated as Significant Military Equipment (SME) shall itself be designated as SME."

23. Paragraph: XII(f)

- **Issue:** This proposed rule classifies some information as Technical Data and Defense Services on the USML. To facilitate the integration of our IR focal plane array into higher order systems, we provide our customers firmware to incorporate into their hardware to interface to our IRFPA. The *Note to paragraph A of note 2 to paragraph (f)* states "Technical data does not include information directly related to basic operating instructions, testing results, *incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category*, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA." This rule is ambiguous as to whether firmware provided to a camera core or camera customer is included on the USML.

Recommendation: Propose amending *note 2 to paragraph (f)* to state that firmware needed for basic operation is subject to EAR.

06 July 2015

Directorate of Defense Trade Controls
DDTCPublicComments@state.gov
Washington, DC

Subject: "ITAR Amendment—Category XII."

Leica Geosystems is pleased to provide these comments in response to the May 5, 2015 Federal Register notice whereby the Department of State, Directorate of Defense Controls(DDTC) solicited comments on the implementation of Export Control Reform (ECR) with respect to fire control, range finder, optical and guidance and control equipment.

It is understandable that DDTC wished to establish clear and unambiguous guidance for items meeting the standards of military equipment. However, it is possible that many of the airborne LIDAR systems already manufactured and shipped internationally by all 3 major commercial suppliers and legitimately shipped under EAR99 classifications would now fall under the USML. These systems have been designed and manufactured for strictly commercial purposes. Furthermore, the current technology trend toward doubling productivity (as defined by effective laser pulse rates) every 2 years could be severely restricted if the proposed rule changes take effect without tailoring.

In particular, the following portions of the proposed changes are troubling, and appropriate comments as well as suggestions for revision are provided.

PROPOSED CHANGES TO SUGGESTED WORDING

Paragraph: (b)(3) "Laser rangefinders having any of the following: (i) Q-switched laser pulse; or (ii) Laser output wavelength exceeding 1,000 nm"

Comment: Many of the current generations of topographic mapping LIDAR systems us q-switched laser subsystems to determine the distance from the survey aircraft to ground below as the system scans the terrain from a moving aircraft. Furthermore, virtually all such systems operate at wavelengths exceeding 1000 nm, the most common wavelengths being 1064nm, 1047 nm and 1550 nm, the latter for enhanced eye safety.

Proposed change; (b)(3) "Laser rangefinders *designed solely for military applications* having any of the following: (i) Q-switched laser pulse; or (ii) Laser output wavelength exceeding 1,000 nm"

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Paragraph: (b)(5) "Systems or equipment that use laser energy with an output wavelength exceeding 710 nm to exploit differential target-background retroreflectance in order to detect personnel or optical/electro-optical equipment (e.g., optical augmentation systems):"

Comment: As mentioned previously, most commercial airborne LIDAR products operate at wavelengths more than 710 nm. Virtually all commercially-applied airborne LIDAR systems provide imagery output based on the intensity of the return reflection from the ground. These intensity images often detect non-diffuse reflectors, such as solar panels, skylights, glazed ceramic roofing, etc. By the same mechanism, these systems might accidentally detect other electro-optical equipment, though this would be a misuse of the technology.

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Proposed change: (b)(5) "Systems or equipment that use laser energy with an output wavelength exceeding 710 nm to exploit differential target-background retroreflectance ~~in order~~ *only* to detect personnel or optical/electro-optical equipment (e.g., optical augmentation systems). *The output of return signal intensity data without preclassification of optical aurmentation systems (i.e., conventional intensity images) shall not be considered in violation of this paragraph:*"

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Paragraph (b)(6) "Light detection and ranging (LIDAR), laser detection and ranging (LADAR),or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);"

Comment: Virtually all commercial airborne LIDAR mapping systems make use of GNSS/IMU hardware. By its nature, most GNSS/IMU subsystems are capable of accommodating both commercial (non-ITAR) and USML-listed IMUs. It is inappropriate to restrict the sale of airborne LIDAR mapping systems solely because they can potentially incorporate an item (e.g., IMU) that is controlled in this subchapter. Instead, the LIDAR system should only be controlled if it actually contains the controlled article.

Proposed change: (b)(6) "Light detection and ranging (LIDAR), laser detection and ranging (LADAR),or range-gated systems or equipment, *specifically* incorporating ~~or specially designed to incorporate~~ an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);"

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Paragraph (b)(8) "LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (i) Systems having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft, and incorporating or specially designed to incorporate a gimbal-mounted transmitter or beam director, and specially designed parts and components therefore;"

Comment: Leica has produces ALS-series systems that have been capable of exceeding the specified point density for a number of years. The current generation of commercial mapping LIDAR systems can achieve a point density of 25 points/m^2 at the specified flying height with a field of view (FOV) of 3 degrees. Furthermore, all ALS-series systems are designed to be installed on the optional PAV100 stabilized platform. It should be noted that the PAV does not direct the laser output to a specific location, but rather keeps the scan pattern centered about a specific orientation (typically nadir).

Proposed change: (b)(8) "LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (i) Systems *specifically designed for military non-mapping applications and* having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft, and incorporating or specially designed to incorporate a gimbal-mounted transmitter or beam director, and specially designed parts and components therefore. *Stabilized platforms designed to keep the LIDAR scan patter at a consistent attitude with respect to nadir are not considered a gimbal-mounted transmitters or beam directors as described above* ;"

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Paragraph (b)((8) “LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);”

Comment: Leica ALS-series systems have been capable of power line detection for over a decade, and the technology has developed to the point that even small-diameter ground wires of 6mm diameter can be readily detected from flying heights of over 1000 m above ground level. In fact, an entire industry has evolved around data capture of both power trans mission lines and power distribution lines for the purposes of vegetation management as well as as-built survey.

Proposed change: (b)(8) “LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (ii) Aircraft systems or equipment designed solely for military use having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);”

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Paragraph (b)(8) “LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geiger-mode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements;”

Comment: Current high-performance commercial mapping LIDAR systems such as Leica ALS-series systems incorporate short-pulse-width lasers that demand electrical bandwidth in excess of 100 MHz. The current generation of ALS-series systems features two linear-mode detectors. The natural evolution of systems is toward scalable architectures, and a natural extension would be toward either larger linear-mode or Geiger-mode detector arrays. Commercial systems from a variety of manufacturers (e.g., 3DEO, Harris, Sigma Space) already use detector arrays with sizes of 100 to 4096 elements, greatly exceeding the proposed limitations. Instead, any such limitation should apply only to systems designed specifically for military applications.

Proposed change: (b)(8) “LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geiger-mode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements *if designed specifically for military applications*;”

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Paragraph (b)(8) “LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (v) Systems or equipment that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs); or”

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Comment: Commercially developed and manufactured systems, such as Leica Chiroptera and Leica HawkEye are capable of detecting various submerged objects that may be hazards to commercial marine navigation. Software does not classify detected objects in the classes given above, though military staff familiar with the characteristics of such devices may be able to determine classification based on the shape or other characteristics of the point cloud produces by the system.

Proposed change: (b)(8) "LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (v) Systems or equipment that *designed specifically for military use that* automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs). *Commercial bathymetric mapping systems not specifically designed to detect the above classes and not automatically providing such classifications will not be restricted; or*"

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Paragraph (b)(8) "LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (vi) Systems or equipment specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;"

Comment: Commercial LIDAR systems are already being employed in autonomous vehicle navigation and obstacle avoidance. Therefore, the envisioned restriction should apply only to such systems specially designed for military use.

Paragraph (b)(8) "LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km): (vi) Systems or equipment specially designed for *military use in* obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;"

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SUMMARY

In summary, the tenor of the above comments is that many commercially-used systems manufactured today already exceed any number of the restrictions proposed. There is no issue in restricting these technologies when designed specifically for military purposes. However, for systems designed specifically for commercial purposes, the benefits of the technology are well documented in terms of reducing the costs associated with surveying large areas or achieving high levels of detail in a given topographic or bathymetric survey. The objective of the proposed rule changes must therefore be to restrict the manufacture or sale or these technologies only when applied to purely military needs.

Leica Geosystems has developed the following systems for commercial mapping purposes:

- Leica ALS40
- Leica ALS50-I
- Leica ALS50-II
- Leica ALS60 and Leica ALS60-CM
- Leica ALS70 (-CM, -HP, -HA)
- Leica ALS80 (-CM, -HP, -HA)
- Leica DragonEye and DualDragonEye

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- Leica Chiroptera
- Leica HawkEye

These systems have been highly successful, with over 250 systems sold worldwide to date for civil mapping applications. These systems have proven themselves to be very effective mapping tools, and are used daily in typical commercial (i.e., non-military) environments. It is our hope that this market can remain open and distinctly segregated from the military markets of concern in the proposed regulations.

I hope the information provided is helpful. If you have any questions, please do not hesitate to contact me.

Best Regards,

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Making the Nation Safe from Fire

A Path Forward in Research

Committee to Identify Innovative Research Needs to Foster Improved Fire Safety
in the United States

Board on Infrastructure and the Constructed Environment

Division on Engineering and Physical Sciences

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Preface

This study was commissioned by the National Science Foundation (NSF) prior to the attack on the World Trade Center in New York on September 11, 2001. That attack led to the fire-induced collapse of three major commercial buildings and the loss of thousands of lives. The report was being finalized when the nightclub fire in West Warwick, Rhode Island, on February 20, 2003, claimed 99 more lives. Both of these events underscore this nation's continuing vulnerability to major fires. It is this committee's view that an incomplete understanding of the phenomenon of fire, the strategies and technologies to control it, and human behavior in chaotic, life-threatening situations contribute to unnecessary human and economic losses. Of course fire is not a new problem in the United States. In 1871 the City of Chicago burned to the ground, destroying the world market center for grain, livestock, and lumber. Over 17,000 buildings were destroyed and 90,000 people were left homeless. While unprecedented, the World Trade Center collapse is yet another exclamation mark in the history of fire devastation in the United States. It does, however, present a new dimension heretofore not fully considered in the design of buildings and civil infrastructure projects—the potential use of fire as a weapon.

Discussion of national fire research needs by distinguished panelists and committee members is also not new. In 1947 President Harry Truman established the President's Commission on Fire Prevention, which featured a committee on fire research. In 1959 the National Research Council's Committee on Fire Research found a dearth of basic research directed toward a fundamental understanding of the phenomena of ignition, fire growth, and fire spread. In 1973 the National Commission on Fire Prevention and Control recommended that federal funding of fire research be increased by $26 million per year ($113 million in today's dollars). Unfortunately, such support for fire research was not forthcoming. In fact, since 1973, federal funding of university fire research has declined approximately 85 percent in real terms.

While the United States continues to have one of the worst fire loss records in the industrialized world, new engineering tools are emerging that offer great hope for higher levels of safety at less cost. Most particularly, new performance-based codes and fire safety design methods are now becoming available. These new approaches not only stand to offer more cost-effective investment of the fire safety dollar but also will permit more reliable prediction of building fire performance and identification of potential catastrophic failure scenarios. Additionally, they will enable the more widespread use of innovative building systems, devices, and methods.

The committee that prepared this report was charged with assessing the state of fire safety research and describing the potential role of the NSF in improving fire safety in the United States. This report highlights markers along a pathway to the future, discusses the nation's fire research needs and the resources that will be required, and suggests a role for NSF and other key agencies and institutions. The committee urges national leaders in government and industry to aggressively support fire research needs, filling voids in the body of knowledge, sharpening engineering tools, and creating a database that will allow performance-based approaches to maximize their contribution to public safety in the United States.

David A. Lucht, *Chair*
Committee to Identify Innovative Research Needs
to Foster Improved Fire Safety in the United States

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Benigno E. Aguirre, University of Delaware,
Howard Baum, National Institute of Standards and Technology,
Doug Dierdorf, Air Force Research Laboratory,
Brian Meacham, Arup,
Jake Pauls, Consultant,
B. Don Russell, Texas A&M University, and
Richard N. Wright, National Institute of Standards and Technology (retired).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Frank H. Stillinger, Princeton University. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Contents

Acronyms

ASCE	American Society of Civil Engineers
BRFL	Building and Fire Research Laboratory (NIST)
FEMA	Federal Emergency Management Agency
FPE	fire protection engineering
HPM	high-performance materials
JFSP	Joint Fire Science Program
NBS	National Bureau of Standards (now NIST)
NCFPC	National Commission on Fire Prevention and Control
NEHRP	National Earthquake Hazard Reduction Program
NFIRS	National Fire Incident Reporting System
NIST	National Institute of Standards and Technology
NRC	National Research Council
NSF	National Science Foundation
PBSD	performance-based seismic design
RANN	Research Applied to National Needs
SFPE	Society of Fire Protection Engineers
USFA	United States Fire Administration
USGS	United States Geological Survey

Executive Summary

The world watched in horror as the towers of the World Trade Center collapsed on September 11, 2001, demonstrating yet again the devastating destructive power of uncontrolled fire. On February 20, 2003, a nightclub fire in West Warwick, Rhode Island, left 99 people dead and more than 150 injured. Not since the 70-year period from 1871 to 1941, during which the Great Chicago Fire destroyed the center of the world market for grain, livestock, and lumber and the Triangle Shirtwaist Factory fire and the Cocoanut Grove nightclub fire killed hundreds, has the ability of fire to cause damage and harm figured so prominently in the national consciousness. However, to those involved in fire safety, the recent horrific events only reinforce the knowledge that fire is a dangerous and relentless foe, and one that is not fully understood or controllable despite years of effort and countless billions spent on prevention, mitigation, and response.

In 1968 Congress passed the Fire Research and Safety Act, which mandated creation of a National Commission on Fire Prevention and Control (NCFPC) to study the nation's fire problem. The commission conducted an in-depth study, held hearings throughout the country, and in 1973 submitted its report, *America Burning,* to the President and Congress. The first page of the report stated as follows: "Appallingly, the richest and most technologically advanced nation in the world [the United States] leads all the major industrialized countries in per capita deaths and property loss from fire" (NCFPC, 1973).

In response to the *America Burning* report, Congress passed the Fire Prevention and Control Act of 1974, which created what is now the United States Fire Administration and the National Fire Academy, currently located within the Federal Emergency Management Agency (FEMA). This legislation also established the Fire Research Center at the National Bureau of Standards—now the National Institute of Standards and Technology (NIST)—thereby providing the basis for the existing program at NIST. As a result of concerted efforts to improve fire safety (particularly the advent of an affordable home smoke detector), residential deaths in the United States have declined since then, but this country continues to sustain unnecessarily high levels of fire-related death and destruction. As part of its strategy to improve fire safety, the NCFPC recommended in *America Burning* that federal funding of fire research be increased by $26 million per year ($113 million in today's dollars). That recommendation was not implemented.

In the early 1970s, the National Science Foundation (NSF) supported fire research at a level of approximately $2.2 million every year ($9.6 million in today's dollars) through a program known as Research Applied to National Needs (RANN). The RANN program was terminated in 1977. Subsequently, a fire research grants program at the National Bureau of Standards (now NIST) was funded at about $2 million annually ($8.7 million in today's dollars). However, by 2002, the NIST fire research grants program had declined to only $1.4 million, a decrease of 85 percent from the 1973 level when adjusted for inflation. As a consequence of the limited funding that has been made available, the scope and breadth of university fire research in the United States have declined dramatically over the past 30 years.

As in any technical field, the production of advanced degree scholars with specialized expertise and career paths in fire science and engineering is critical to both conducting the needed research and training the next generation of investigators, teachers, and practitioners. Unfortunately, reduced research funding over the past three decades has caused U.S. production of career-directed young men and women who will make and implement the important fire safety discoveries of the future to all but dry up.

In recognition of the slow pace of advancement in the fire safety field, the paucity of basic research, and the small number of universities offering research and training opportunities, NSF asked the National Research Council (NRC) to help it determine how to align its programs and resources to advance fire safety in the United States. The Committee to Identify Innovative Research Needs to Foster Improved Fire Safety in the United States was appointed to plan and conduct a workshop that would survey and assess the current state of knowledge, research, education and training, technology transfer, and deployment of practices and products in the fire safety field. The committee also set out to help define how NSF could marshal the intellectual, financial, and institutional resources of the United States to develop the knowledge necessary to save lives and reduce injuries and property loss from fire. The workshop was held on April 15 and 16, 2002, and attended by more than 50 national and international experts from various disciplines involved in fire safety.

During the course of the workshop, many themes emerged from the perspectives of the different disciplines represented. However, the committee's overarching conclusion is that there are significant gaps in our knowledge of fire safety science and fire loss mitigation strategies. As a result, the threat posed by fire to people, property, and economic activity is neither well understood nor fully appreciated. The ramifications of these gaps manifest themselves in many ways. For example, the need for a sound and complete knowledge base has never been greater in light of the recent emergence of performance-based codes published by the International Code Council (ICC, 2001) and the National Fire Protection Association (NFPA, 2003) and performance-based design practices such as those released by the Society of Fire Protection Engineers (SFPE, 2000). Performance-based codes and design practices provide a real opportunity to make buildings safer at less cost and further open the doors to innovative building systems, devices, and materials. However, current knowledge gaps force engineers and regulatory officials to apply performance-based practices in a climate of significant uncertainty: For instance, could other buildings suffer catastrophic failures like those that occurred on September 11, 2001, at New York's World Trade Center? In other words, substantial amounts of money continue to be invested in building fire safety features without the benefit of scientifically informed expectations of the resulting safety performance. As a result of the workshop presentations and discussions and its own subsequent deliberations, the committee found significant knowledge gaps in eight topical areas:

- *Fire and explosion fundamentals*. Behavior of fire in buildings where the fire itself has induced changes in compartment geometry and venting; improved prediction from first principles of flame spread and extinction over condensed-phase fuels; explosion phenomena.
- *Materials and retardants*. Coatings, catalysts, additives; smoke and toxicity; melt, flow, and dripping; pyrolysis and flammability; high-temperature performance.
- *Fire protection systems***.** Chemical and physical suppression and extinction phenomena; smart suppression; multiple signature detection.

- *Engineering tools***.** Modeling fire growth, detection, and suppression system performance; hazard analysis and probabilistic risk assessment methodologies; uncertainty analysis; fire scenario definition and quantification.
- *Structural fire performance*. Fuel loads; fire severity and fire-induced changes in geometry and venting; high-temperature properties of materials; performance of structural connections; development and verification of analytical methods.
- *Human behavior***.** Evacuation modeling and data; stair flows and counter flows; group dynamics and decision making; post-9/11 human perceptions and behaviors; effects of toxic products; human factors.
- *Public policy***.** Decision-making methods and validation; quantification of fire severity and frequency; public safety goals; relationship between public policy and technical risk analysis.
- *Data***.** Fuel load, distribution of building contents; explosion losses; thermodynamic, thermophysical, and thermochemical material property data; quantification of model uncertainty; human behavior data for building evacuation models; cost/loss metrics.

Identifying priorities among such a wide range of research needs is a significant challenge and beyond the scope of a single workshop. As noted by the various workshop presenters, almost all areas connected with fire safety will benefit from additional resources and intellectual effort. Because NSF has traditionally served as an incubator for coordinated, interdisciplinary research programs for hazard reduction that involve the university research community, government agencies, and the private sector, the committee identified NSF as the most logical agency to support a new university grants program in fire research, not only to help advance the state of knowledge but also to support the production of young scholars—the human capital so badly needed for the future of U.S. fire safety science and engineering. At the same time, the committee believes that NSF has an opportunity to act as a catalyst for a well-coordinated program of improved fire safety.

The committee's findings and recommendations are presented as a path forward for NSF to expand its role in making the nation safe from fire.

FINDINGS

The High Cost of Fire. Unwanted and preventable fire in the United States continues to exact an unacceptably high cost in terms of human suffering and economic losses. The threat to people, property, and economic activity is neither well understood nor fully appreciated by policy makers and the public at large.

Benefits of Performance-Based Practices. Performance-based building codes, which are now available in the United States for adoption by state and local governments, offer real promise for regulators and public officials to institute regulations that reflect a better understanding of risks and improved safety performance for buildings in their communities. However, performance-based codes depend on the ability of engineers to predict how buildings will perform under fire conditions. There are significant gaps in the data and knowledge base needed to support performance-based codes, engineering tools, predictive models, and risk assessment.

Insufficient Funding. The current funding levels and organizational infrastructure for fire research in the United States are inadequate to address even the most fundamental research needs that were raised at the workshop and subsequently discussed by the committee. The documented costs of unwanted fire, in both human and economic terms, justify substantial investment in fire safety research and the development and deployment of the products of that research. The public at large, businesses, institutions, and government agencies can all benefit from better safety at less cost.

Coordination and Cooperation. Improving fire safety in the United States depends on the combined efforts of a range of disciplines and communities, from fire researchers and academics to the fire services, public officials, codes and standards groups, private industry, government agencies, and professional societies. There is a need for better communication, cooperation, and integration of national fire safety efforts.

Important Role for Universities. University-based fire research has all but evaporated in the United States over the past three decades. In addition to choking off new scientific discovery, this turn of events has all but eliminated the production of young scholars with a career commitment to inquiry and teaching in the fire safety sciences.

Role of the National Science Foundation. The NSF has traditionally served as an incubator for coordinated, interdisciplinary research programs for hazard reduction that involve the university research community, government agencies, and the private sector. As compared with more mission-oriented agencies, an NSF commitment can be particularly beneficial in areas of basic research that will improve our understanding of the nature of fire; its detection, suppression, and control; technology applications (e.g., next-generation residential smoke detectors, material coatings, and intrinsically safe home appliances); human behavior; and interdisciplinary studies to better inform building codes, design, and regulatory/public policy processes.

The National Earthquake Hazards Reduction Program Model. Through NEHRP, the U.S. government has aggressively pursued such an integrated approach for addressing the earthquake hazard. Its approach has resulted in greatly improved building performance and reduced levels of injury and death.

RECOMMENDATIONS

> **1. NSF should reestablish and fund a program in basic fire research and interdisciplinary fire studies. Funding of approximately $10 million per year is recommended to initiate this effort. This initial funding level would restore the NSF investment in fire research to its 1973 level (in today's dollars). It should be reconsidered once a robust research infrastructure is in place.**

The level of fire research at U.S. universities has declined greatly since the RANN program was terminated at NSF. Given NSF's charter to support basic research and education, the committee believes that NSF is the appropriate agency for administering a reinvigorated and robust university grants program in fire research. Funding of university principal investigators and graduate students needs to be emphasized, both to accomplish research goals and to invest in the nation's next generation of investigators and teachers—the human capital so necessary for continuous improvement in fire safety. There are many on-going initiatives and programs within NSF (e.g., nanotechnology, sensors, high-performance materials, surface chemistry, human and social factors in hazard mitigation, structural system performance) that could provide a logical nexus (not to speak of existing funding) for reestablishing a comprehensive and interdisciplinary focus on fire safety within NSF.

This report makes no attempt to suggest a national research agenda or to identify fire research priorities for the nation. Such prescription was beyond the scope of this effort. The committee believes that work previously done by others, such as the SFPE Research Agenda 2000, the United States Fire Administration (USFA), and the Joint Fire Science Project (JFSP), along with the discussion of topical areas found in this report, will serve as a valuable resource for evaluating initial research proposals. In the short term, NSF can make use of this report and recent work by others to evaluate research proposals. The committee believes that the recommended funding level of $10 million annually would be an appropriate starting point for supporting multiple investigators in the physical, social, and behavioral sciences and engineering, with an emphasis on fostering interdisciplinary activities. In the longer term, NSF should coordinate its efforts with other agencies to build an integrated and robust research infrastructure for fire safety. Once such an infrastructure is in place, higher funding levels (such as those recommended in *America Burning*—approximately $113 million in today's dollars) should be considered. The committee would note that significant resources are already available through the multiplicity of mission-directed fire safety activities currently under way in federal agencies. Better coordination of existing fire safety planning, research, and implementation and their integration under a renewed initiative by NSF could create significant opportunities to leverage research dollars, increase technology transfer, and speed deployment of new methods and products.

2. A coordinated national attack to increase fire research and improve fire safety practices should be launched. The committee recommends that NSF support exploratory activities to determine if a model such as NEHRP or any other model that combines integration, cooperation, stakeholder involvement, and collaboration in research could hasten the development and deployment of improved fire safety practices through more coordinated, better targeted, and significantly increased levels of fire research in the United States.

Many workshop participants emphasized that, in addition to addressing the paucity of basic research, there also needed to be better coordination, cooperation, and communication among the stakeholders in national fire safety. The United States lacks an adequately funded and well-coordinated national fire research program such as that for earthquake engineering embodied in the NEHRP. Most federally funded fire research is mission-focused and conducted by user agencies, which show little interest in leveraging the research investment, supporting graduate students, or transferring technology. Given the emergence of performance-based design and regulatory practices, the fire safety field is desperately in need of integrated research findings targeted to the priority needs of practice. A number of possible national strategies for achieving this goal were discussed at the workshop. The committee believes that a national attack on the U.S. fire problem requires interdisciplinary communication, cooperation, and coordination supported by adequate funding. The earthquake safety movement, which began in the 1970s and has evolved into the successful NEHRP is an excellent model for the fire safety community to consider. An effort modeled on the NEHRP could engage all federal agencies currently involved with fire safety and, at a minimum, should link a reinvigorated NSF university grants program with the valuable efforts currently under way at other agencies, such as the National Institute of Standards and Technology and the U.S. Fire Administration.

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Introduction

Death rates from unwanted fires in the United States are among the highest in the industrialized world. Despite declines for residential fire death rates over the past 25 years, the U.S. remains a world leader in fire losses (Geneva Association, 2002). The total cost of fire in the U.S. (fire losses plus the costs of fire safety measures) is estimated between $100 and $200 billion per year (Hall, 1999) or between 1 and 2 percent of the gross domestic product. These figures describe a serious national problem, and even though it has been mitigated somewhat by advances in applied research to improve fire safety, basic research into the nature of fire, its causes, characteristics, and effects on people, products, structures, and the environment have the potential to further mitigate the problems. Further improvements in design, construction, and loss reduction strategies that will protect constructed facilities and the people and equipment housed within them are still possible. However, these gains will only be realized if the knowledge base is continually expanded through basic and applied research that has a ready path into practice.

BACKGROUND

In 1968 Congress passed the Fire Research and Safety Act, which mandated creation of the National Commission on Fire Prevention and Control to study the nation's fire problem. The commission conducted an in-depth study and held hearings throughout the country. In 1973 it submitted its report, *America Burning,* to the President and Congress. Page one of the report stated as follows: "Appallingly, the richest and most technologically advanced nation in the world [the United States] leads all the major industrialized countries in per capita deaths and property loss from fire" (NCFPC, 1973).

America Burning offered 90 recommendations for addressing the American fire problem. Among them were creation of the United States Fire Administration (USFA) and the National Fire Academy for the nation's fire services. These agencies were created under the Fire Prevention and Control Act of 1974 and are now functioning within the Federal Emergency Management Agency (FEMA). This same legislation established the Fire Research Center at the National Bureau of Standards—now the National Institute of Standards and Technology (NIST)—thereby consolidating existing programs.

Under the topic "Research for Tomorrow's Fire Problem," *America Burning* also recommended a $26 million increase in federal funds for fire research ($113 million in today's dollars). That recommendation was never acted on.

During the 1960s and early 1970s the NSF Research Applied to National Needs (RANN) program did have a fire research element, under the direction of Ralph Long. RANN funded university professors and graduate students at a host of universities including Harvard, Massachusetts Institute of Technology, Brown, Princeton, the University of California at

Berkeley, and others. The funding was approximately $2.2 million per year in 1973 ($9.6 million in today's dollars). The RANN program was terminated in 1977.

Subsequently, a fire research grants program at NBS was funded at approximately $2 million annually ($8.7 million in today's dollars). Later on, however, funding for the NBS fire program was reduced, so that both the in-house and grants programs declined. NIST currently administers vestiges of the grants program, at a level of approximately $1.4 million (in today's dollars). Adjusted for inflation, this fire research grants program has declined nearly 85 percent. As a result, there is no credible university grants program for fire research supported by the federal government today.

Aside from the extramural fire research grants program at NIST, full-time government employees perform substantial in-house research. It is reported that over the past decades the number of NIST fire research staff declined by more than 50 percent (Lyons, 2002). Moreover, funding for in-house NIST fire research no longer comes primarily from direct congressional appropriation—about half now comes from other agencies. Quintiere has made a strong case for change: "Research funding has been all but eliminated for fundamental studies in fire. These fundamental studies are essential for developing the infrastructure of the discipline and the practice of fire protection engineering" (Quintiere, 2002).

In 2002, the Society of Fire Protection Engineers (SFPE) performed a study of federally funded fire research. It identified a total of $37 million in fire research support among 11 agencies (SFPE, 2002). The preponderance of this support targets shorter-term mission support functions. About 87 percent is used to support federal salaries, contractors, and consultants. About 13 percent ends up supporting university professors and graduate students. It is not known what fraction, if any, is focused on longer-term, higher-risk basic research.

INVOLVEMENT OF THE NATIONAL RESEARCH COUNCIL

NSF, recognizing its potential role in fostering a strong research base to support improved fire safety activities, requested that the National Research Council (NRC) create a committee to plan and convene a 2-day workshop to assess the state of knowledge in fire safety and suggest ways the NSF could align its programs, resources, and collaborations to help advance fire safety in the United States. In response to that request, the NRC assembled an independent panel of experts, the Committee to Identify Innovative Research Needs to Foster Improved Fire Safety in the United States, under the auspices of the Board on Infrastructure and the Constructed Environment. The 16 members of the committee have expertise in fire safety, fire science, fire protection engineering, structural engineering, polymer chemistry, materials performance, building codes and standards, architecture, emergency response, human behavior, and disaster and crisis management. Biographical information about the committee members is provided in Appendix A.

STATEMENT OF TASK

The committee was charged with convening a 2-day workshop to survey and assess the current state of knowledge, research, education and training, technology transfer, and deployment of practices and products in the fire safety field. The objective for the workshop was to define how best to marshal U.S. intellectual, financial, and institutional resources to develop the needed knowledge and break down the barriers to improvements in building design, construction methods, materials, and operations and maintenance that will save lives and reduce injuries and property loss from fire. Although the state of fire research and the research infrastructure were important topics of discussion, the workshop did not seek to develop a research agenda, building instead on recent efforts to identify research needs (e.g., SFPE, 2000). Similarly, the relative merits of performance-based codes and prescriptive approaches were not to be a focus issue, although the question of how best to develop a science base to support performance-based codes was. A critical question for workshop participants was how best to take advantage of NSF-sponsored cutting-edge research in materials and applications that can improve fire safety.

The workshop presentations paid particular attention to the barriers that exist at the intersections of disciplines and institutional sectors as well as to the opportunities that these intersections provide for interdisciplinary research to eliminate barriers. Although these areas often tend to be overlooked by discipline-based activities, the barriers are frequently the primary inhibitors of progress. The outcome of the workshop and the subsequent committee meeting was a clearly articulated statement of research, education, and technology-transfer needs for improved fire safety in the United States, the resources necessary to meet them, and a path forward for NSF and other key U.S. science and technology agencies and institutions.

ORGANIZATION OF THE WORKSHOP

The Workshop to Identify Innovative Research Needs to Foster Improved Fire Safety in the United States was held on April 15 and 16, 2002, in Washington, D.C. In addition to committee members, 36 internationally recognized experts from academia, government, and industry attended the workshop (Appendix C). The participants were chosen for their expertise in fire science, fire protection engineering tools, human behavior, and regulatory processes and represented a broad range of perspectives. The morning of the first day provided a glimpse of the present "fire problem" in the United States. There was also a presentation describing the development of the National Earthquake Hazards Reduction Program (NEHRP), which was offered as a model for improving safety. The remainder of the first day and most of the second day were devoted to invited presentations and moderated discussion focused on seven topics:

- Fire and explosions
- Materials and retardants
- Fire protection systems
- Fire protection engineering tools
- Structural performance
- Human behavior
- Public policy

The invited presenters were requested to submit written papers prior to the workshop to summarize the state of the art in their particular area of expertise. The papers and workshop presentations are included on a CD-ROM that is part of this report.

After the workshop, the committee developed its findings and recommendations for research areas that should be pursued and strategies that could be implemented by NSF and others. The observations, findings, and recommendations for further research, which are presented in this report, are based on discussions facilitated by the workshop and the knowledge and experience of committee members. This report does not purport to be a comprehensive state-of-the-art assessment; rather, it reflects the consensus of the committee on what was learned at the workshop and in subsequent discussion. The report is intended to serve as resource for NSF and others in setting research priorities and evaluating proposals. Although the knowledge and participation of the workshop attendees were invaluable for the preparation of this report, the findings and recommendations represent the judgment of the NRC committee that was appointed for this purpose. The responsibility for the final content of the report rests entirely with the committee and the National Research Council.

From the outset it was recognized that other groups, most recently the Society of Fire Protection Engineers (SFPE, 2000), had already done excellent work on a national fire research agenda. In 1999, with funding from NIST, the SFPE conducted a comprehensive research needs workshop in Washington, D.C. This involved more than 70 fire science, engineering, and business leaders from virtually all sectors, working in a structured 2-day workshop format. The end result was the SFPE Research Agenda Report, dated February 2000. It identified priority research needs in four areas: risk analysis, fire phenomena, human behavior, and data. The SFPE effort defined"fire research" broadly and went well beyond the traditional thermodynamics and fluid dynamics of ignition and combustion phenomena. The findings of the SFPE workshop helped to shape the agenda for the current study.

ORGANIZATION OF THE REPORT

The following chapters provide additional background and contextual material on the evolving practice of fire-related design for buildings and infrastructure. The unique role of universities is discussed, and a few comments are offered on the fire-induced structural collapse of the World Trade Center buildings. A more complete description of NEHRP is also presented.

Chapter 2, organized broadly along the lines of the workshop, covers specific areas of research that are believed to need attention. Every effort has been made to include all of the topics covered in the workshop. Extensive use is made of bulleted lists to give the reader a convenient overview of the spectrum of research needs. Each bullet is an excerpt or paraphrase taken from one of the workshop participants or authors. All papers are found on the CD-ROM, giving the reader the opportunity to refer directly to a paper for the context surrounding excerpts or paraphrases found in the bullet lists. Chapter 3 contains the findings of the committee and its recommendations for a path forward.

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Workshop Synopsis

Many workshop participants pointed out that design, evaluation, and regulation of fire safety for buildings have undergone a sea change since the 1970s. While buildings were traditionally evaluated and regulated with reference to a checklist of specific code requirements, the trend, worldwide, has been toward performance-based approaches, with the United States lagging behind other developed countries in adopting these approaches. While performance-based building codes were implemented in countries such as the United Kingdom, Australia, and New Zealand in the 1980s and 1990s, the first model performance-based building code in the United States was not published until 2001 (ICC, 2001). At the time of the workshop, April 2002, no U.S. state or local jurisdiction was known to have adopted one of the model performance-based building codes.

In practice, performance-based codes rely much more heavily on fire research, basic theoretical understandings, data, and the ability to predict building safety performance under fire conditions. While in the past it was sufficient to establish that a building met the code, in the future there will be more and more pressure on engineers to predict safety performance under fire conditions. As a result of these discussions, the committee concluded that the scientific foundation is incomplete in terms of its ability to support predictive modeling with an acceptable level of uncertainty.

THE ROLE OF THE UNIVERSITY

During the 1960s and early 1970s principal investigators at several U.S. universities received ongoing support for fire research under the NSF/RANN program. While modest in scale, this program not only strengthened the body of knowledge but also expanded the nation's human resource infrastructure by training graduate students who went on to research, teaching, and practice.

Perhaps the most significant example of this was the work of Howard Emmons at Harvard. With ongoing NSF/RANN fire research support, Dr. Emmons was able to sustain a small community of first-rate scholars with a focus on fire fundamentals. Through the years, he and his graduate students were able to unlock new understanding of fires in buildings and produce the first generation of mathematical fire models. Dr. Emmons is now regarded as the father of computer fire modeling. During his career, he guided 51 Ph.D. graduates, a few dozen of whom went on to dedicate their own careers to fire safety.

The production of advanced degree scholars with a specialized expertise and career interest in fire science and engineering is extremely important for the nation. It is these men and women who will make the discoveries of the future. Unfortunately, the production of career-directed young investigators in fire safety has all but dried up in the United States over the past three decades as research funding has severely declined in real terms.

It should also be noted that a robust understanding of the fire performance of a building requires an array of many disciplines—from combustion and materials science to human behavior, architecture, and public policy. In the 1960s and early 1970s most university fire research was performed in departments of chemical, mechanical, or civil engineering. Since then, graduate studies in fire protection engineering have emerged here and worldwide. In the United States, two M.S. degree programs in fire protection engineering were launched, one in 1979 at Worcester Polytechnic Institute (WPI) and one in 1990 at the University of Maryland (UMD). A Ph.D. program in fire protection engineering began at WPI in 1991. Brady Williamson and Pat Pagni at the University of California, Berkeley, have graduated a number of Ph.D. students with excellent research backgrounds in fire safety science, some of whom went on to teach at WPI and UMD. These universities represent a new national resource for the United States, each offering an ongoing scholarly focus on the broad, integrated area of fire science and engineering. However, despite these educational programs, overall support for fire research and education in the United States has declined dramatically.

A sustainable emphasis on fire safety and security can only be maintained through viable educational and research programs that create new knowledge and produce educated research professionals. Universities are highly selective in determining which research and education programs will be fostered and maintained, and without research funding, no research or teaching programs can be viable. Research dollars are the "without which nothing" (including formal fire safety programs) can thrive in university environments.

The workshop participants identified numerous specific training and education needs:

- Formal academic courses in explosion protection are extremely scarce in U.S. universities and colleges (Zalosh).[1]
- New human capital must be produced for utilizing and advancing existing tools, as well as for developing future tools….Academically based fundamental research is critical (Dryer).
- There has been an almost complete demise of basic fire research activity at universities (Dryer).
- Currently there is very limited graduate training in fire chemistry as it requires the interaction of chemists and civil engineers. Cross-disciplinary knowledge and training are needed (Pearce).
- We need an interdisciplinary and holistic approach to materials processing and structural design for fire durability (Riffle).
- Young people at the assistant professor or associate professor level (in the area of chemistry and materials science aspects of fire science) are practically nonexistent in the United States. The United Kingdom, France, Italy, China, Japan, and Russia appear to be training more young people in this area than is the United States (Weil).
- Students must be taught performance-based structural fire performance analysis (Iding).

[1]Throughout this report, the callouts without dates refer to committee members who expressed the opinion or provided the information in the course of workshop discussions or to participants who did the same in the papers they had prepared for the workshop. The background papers are contained on the CD-ROM that accompanies this report.

- Concepts in risk characterization, uncertainty, variability, and decision-making processes and tools should be a component of education and training for those at all levels of the regulatory, design, and enforcement communities (Meacham).
- Colleges, universities, and professional organizations could more effectively collaborate to offer practical courses and seminars to decision makers in the art of transferring fire safety technology through public policy (Kime).

A WORD ABOUT THE WORLD TRADE CENTER DISASTER

The FEMA/ASCE report on the September 11, 2001, World Trade Center collapse was released in April 2002 (FEMA, 2002). The report made clear that Towers One and Two withstood the physical impact of the aircraft and that the collapse of both towers was fire induced.

Although it is generally understood that the thermal impact of the burning jet fuel, which resulted in the almost simultaneous ignition of the building contents, was a worst-case catastrophic event for the structures, the FEMA/ASCE report does raise questions about our basic understanding of several areas of building fire performance, including fire loadings, fireproofing, structural connections, emergency communications, and human behavior. These areas were spotlighted and discussed during the workshop.

In August 2002, Congress appropriated $16 million to FEMA, which in turn is funding NIST to continue the investigation of the World Trade Center collapse. Although this investment to increase our understanding of that event is laudable, the investigation should not be regarded as a surrogate for the huge amount of sustained fundamental fire research needed in the United States. In fact the need for such an investigation is symptomatic of the inadequate body of knowledge that exists regarding the fire performance of structures.

THE NATIONAL EARTHQUAKE HAZARD REDUCTION PROGRAM AS A MODEL

Earthquake engineering may be an instructive analogy for enhancing fire safety through interdisciplinary research, application, and technology transfer. Earthquake research has had considerable success in changing regulatory attitudes and construction paradigms and moving improved designs, techniques, and materials into practice. This success has been facilitated to a large degree by a network of academic and government research institutions integrated with the educational, design, and regulatory communities. These partnerships can trace their history to action at the federal level in response to unacceptable losses from devastating earthquakes in the 1960s and 1970s. The NSF, the principal government agency charged with support of basic research, has teamed with other federal agencies to support basic earthquake research in the physical, natural, and social sciences, the code and standard development process, engineering applications, and technology transfer. This effort has been successful partly because it addresses the issues from an interdisciplinary perspective and permits all stakeholders to participate in the process.

The National Earthquake Hazards Reduction Program (NEHRP) was an important outcome of the national movement to improve earthquake safety. It was created in 1977, when Congress passed the Earthquake Hazards Reduction Act (P.L. 95-124). This act was significantly amended in 1990 with the National Earthquake Hazards Reduction Program Act (P.L. 101-614), which refined the description of the agencies' responsibilities and the program's goals and objectives. FEMA is the lead agency for this program, but NSF, NIST and the U.S. Geological Survey (USGS) also participate. Each of the agencies is tasked with certain functions that contribute to our understanding of earthquakes and that enhance safety in the face of them:

- In addition to coordinating the program, FEMA manages the federal government's response to earthquakes, funds state and local preparedness activities, and supports the development of improved seismic design and construction.
- USGS conducts and supports earth science research into the origins of earthquakes, predicts and characterizes hazards, and disseminates earth science information.
- NSF funds earthquake engineering research, basic earth science research, and earthquake-related social science research.
- NIST conducts and supports studies related to improving the provisions in building codes and standards that deal with the effects of seismic events.

The total appropriations for the program over the last 3 years has been just slightly more than $100 million per year split unevenly between the four agencies. Similar to NSF's RANN program and its successor (the program at NIST), the funding for NEHRP has also declined significantly in constant dollars since the late 1970s. However, NSF is still providing approximately $30 million per year for earthquake research (NRC, 2002).

Regardless of the decline in real dollars, the NEHRP program has been lauded over the last 25 years for its significant contribution to improving the ability to anticipate and mitigate earthquake damage. An NSF/FEMA-supported project has resulted in the development and periodic update of nationally applicable earthquake design provisions for new buildings. These provisions, which are being incorporated into national building codes and ASCE standards, form the basis for the *International Building Code* (ICC, 2001). NEHRP has also been directly supporting the drive toward performance-based seismic design (PBSD) through FEMA's sponsorship of an effort by the Applied Technology Council (ATC, 2002). FEMA's Existing Building Program has culminated in the publication of FEMA standard 273 for performance-based rehabilitation of buildings. In other NEHRP activities, social scientists supported by NSF have created new tools for understanding the public policy, economic, and societal factors, such as community decision making, that guide state and local adoption of measures to reduce future earthquake losses. To better focus NEHRP resources and create an infrastructure for coordination, NSF decided to reorganize and expand the National Center for Earthquake Engineering Research into three distinct university-based earthquake engineering research centers, indicating a national commitment to multidisciplinary research and outreach. Additionally, NSF and the USGS fund the Southern California Earthquake Center as a science and technology center, and NSF has established the Network for Earthquake Engineering Simulation (Arnold, 1998).

NEHRP demonstrates that a consensus to invest in risk reduction can be achieved by active collaboration among scientists, engineers, government officials, and business leaders and by their interaction with an informed public. The program also demonstrates that leadership and political effectiveness are key elements in developing a successful program.

Although earthquakes and fires both pose serious threats to the American public and the national economy, they are fundamentally different hazards. Serious earthquakes are relatively rare, but a single large earthquake can be catastrophic. Fire events, while far more frequent, are much less likely to cause catastrophic damage to the infrastructure of an entire community. For example, earthquakes have caused, on average, fewer than 10 deaths per year in the United States over the past 25 years (USGS, 2002), but just two events, the Northridge earthquake in 1994, which killed 60 persons and caused over $20 billion in damages and the 1989 Loma Prieta earthquake, which killed 63 and caused over $6 billion in damages, account for 85 percent of the deaths and a quarter of the damage in that time frame (Cutter, 2001). Fires, on the other hand, caused, on average, 5,400 deaths annually during the same period (NFPA, 2002) and are estimated to cause about $10 billion annually in direct property loss (Hall, 1999). In addition, the events of September 11, 2001, demonstrated that fire can pose a potentially catastrophic threat, even to large, robust commercial structures.

AREAS WITH KNOWLEDGE GAPS

As indicated above, the overall goal of the workshop was to identify areas where there are gaps in our knowledge of fire and to explore the potential role of NSF in supporting the research that would fill in those gaps. Continued enquiry into the nature of fire, and its causes, characteristics, and effects on people, products, structures, and the environment can result in even further gains toward the ultimate goal of saving people and property. Improvements in design, construction, and loss reduction strategies for buildings and facilities can be realized if new knowledge, developed through research, has a ready path into practice and the marketplace.

The eight areas where participants found knowledge gaps are discussed next. Identifying priorities among them is a significant challenge and beyond the scope of a single workshop. As noted by the various workshop presenters, almost all areas connected with fire safety will benefit from additional resources and intellectual effort.

Fire and Explosions

Our fundamental understanding of fire has progressed enough in the past 40 years to allow development of the range of engineering methods used today. However, this understanding is still incomplete. Fire and explosion behavior can be predicted only with a thorough grasp of the complex physical interactions that take place. As mentioned earlier, the support of basic fire research at universities has dwindled from what it was in the 1960s and 1970s (NSF/RANN) to what remains in the NIST Building and Fire Research Laboratory (BFRL) extramural grants program. Consequently, the performance codes being introduced in the United States lack the necessary science and technology foundation. Fire tests and standards are developing without a science base to support them or to understand and account for uncertainties. The United States simply cannot afford to have an empirical basis for its fire safety infrastructure but needs instead a science base to build new, more predictive fire models and tools for performance-based design.

The following exemplify the kinds of knowledge that are needed to understand fire and explosions:

- The properties of turbulent flow phenomena in general and turbulent combustion in particular are still poorly understood and likely to remain so for decades to come (Baum).
- The most urgent problems peculiar to fire research occur at the interface between the gas- and condensed-phase materials (Baum)
- The geometry and construction materials of a building need to be defined while at the same time recognizing that the underlying geometry of the building can be altered by the fire and that this affects how the fire behaves and therefore the impact on the structure (Baum).
- There is need for explosion research in (1) flame speeds in highly nonuniform gas-air mixtures, (2) deflagration-to-detonation transitions in congested and turbulent environments, (3) dust cloud formation that can lead to dangerous secondary dust explosions, (4) blast wave propagation in buildings, and (5) blast wave generation of secondary fragments and the development of blast resistant/compliant windows (Zalosh).
- The present level of fundamental knowledge is insufficient for predicting gas-phase extinction (Dryer) and worse for predicting the extinction of flames from solid materials (T'ien).

Materials and Retardants

Advances in flame-retardant polymers and their composites, together with improved predictive capabilities, could reduce the fuel loads due to contents and structural components, reduce the toxicity of combustion products, and allow for longer egress times during fires. Increasing the fire retardancy of structural polymeric composites will also overcome a potential barrier to the more widespread use of these composites, which could also reduce construction time and labor costs.

Important insights mentioned during the workshop include these:

- [Research is needed in] (1) protective, flame retardant, and intumescent coatings, (2) smart polymers and additives, and (3) flame retardant systems operating by catalytic mechanisms (Weil/Pearce).
- Our poor understanding of smoke and toxicity is a critical barrier to the further incorporation of polymers and their composites in building contents and structural applications (Weil/Pearce).
- The literature contains only a few systematic studies of polymer melt, melt flow, and dripping to determine their quantitative effects on fire growth (Kashiwagi).
- Significant improvements are needed in understanding the high-temperature and flammability properties of materials (Mowrer).
- More knowledge about the effects of temperature and heat flux on the mechanical properties of polymeric materials is needed for simulating the structural response of buildings in a fire (Riffle/Lesko).
- There are no fiber-reinforced polymeric materials suitable for all critical fire applications in buildings (Riffle/Lesko).

Fire Protection Systems

Fire detection is the first step to taking mitigating actions, which include evacuating or relocating people, notifying responders, or initiating other strategies such as smoke control and fire suppression. Commercial efforts have focused on developing detection devices that are less prone to unwanted (nonfire) actuation without sacrificing speed of operation or that are more stable without sacrificing sensitivity. Using innovative sensor technologies and signal analysis, fires can be detected with greater speed, accuracy, and clarity. However, developing improved detection devices does not improve fire defenses, protect responding fire fighters, or provide more cost-effective, performance-oriented design. Successful application of new sensor technologies depends on the integrated development of better engineering tools to model the fire stimuli and detection device response to those stimuli. This type of research is well-suited to interdisciplinary teams that include practitioners of the social and decision sciences as well as engineers and physical scientists. In a systems context, there is an underlying need for the sensors to sense what they need to and nothing more and for the actuators to know when and what to actuate and to do so quickly. This is not a problem for engineers alone to solve.

Fire suppression research in recent years has largely focused on replacements for halogenated hydrocarbons (halons). The development of new fire suppression strategies, agents, and methods will require a better understanding of the chemical and physical phenomena of fire suppression and flame extinction. Without breakthroughs in research on fire suppression phenomenology, costly trial-and-error approaches to system development and design will continue.

Some key insights contributed by workshop participants include the following:

- The development of new fire suppression strategies, agents, and methods will require a better understanding of the chemical and physical phenomena of fire suppression and extinction (Dungan).
- Continued research is needed in the area of multisignature detection, particularly detectors for gas and smoke combinations, which hold greater promise for improved performance than detectors for smoke alone (Gottuk).
- Low-cost sensors for gases, particularly CO and CO_2, that are stable and have a functional life of 10 years or more [must be developed in order] to produce marketable multisignature detectors (Gottuk).
- Owing to the large numbers of deaths and injuries in residential fires, there should be more research on improving detection for residential applications (Gottuk).
- Reducing the frequency of nuisance alarms should be a key objective for new fire detection technologies (Gottuk).
- It would be advantageous to have a detection method that could be used for monitoring hazardous chemicals and conditions in addition to providing fast, reliable fire detection (Rose-Pehrsson).
- One can imagine future advances in fire suppression through smart suppression based on scenario-specific engineering analysis (Hamins).
- Research is needed on the complicated multiphase processes by which a condensed-phase agent extinguishes a fire (Hamins).

- A better understanding is needed of the chemical mechanisms associated with halon replacements to provide a scientific basis for improved design of suppressant systems (Hamins).
- A better understanding of agent mass and heat transfer processes would provide a scientific basis for the creation of rational engineering tools and improved suppressant system design (Hamins).

Fire Protection Engineering Tools

In the context of this document, fire protection engineering tools include deterministic fire hazard analysis models and probabilistic fire risk assessment methodologies. These tools permit the hazards and risks associated with fire to be evaluated quantitatively in terms of physically meaningful units of measure. The development of these tools over the past few decades has prompted, as well as permitted, the development of frameworks for the performance-based fire safety analysis, design, and regulation of buildings. Continued development and refinement of these tools and methodologies is needed to implement more fully the rational, more economical performance-based approaches to building fire safety that are based on known levels of safety, risk, and uncertainty.

Until now, advances in fire protection engineering tools have been evolutionary. However, performance-based codes and standards, supported by a new generation of fire protection engineering tools, may truly be revolutionary advances. For this reason, research into both deterministic fire hazard assessment and probabilistic fire risk assessment is encouraged. Inputs from workshop participants and committee members included the following:

- With the increasing use of performance-based fire protection design, it is imperative that predictive tools and methodologies be available to design and analyze fire detection systems (Gottuk).
- Continued development of deterministic fire hazard analysis models and probabilistic fire risk assessment methodologies is needed to more fully implement rational performance-based approaches to building fire safety (Mowrer).
- Models, tools, and data are needed to quantify uncertainty associated with input parameters and models for conducting probabilistic fire safety assessments (Siu).
- From a national fire safety improvement standpoint, it is essential to identify the scenarios that dominate national fire risk (Siu).
- Models of gas-phase suppression are limited by the use of simple zero or one-step combustion mechanisms in large-scale simulations. Detailed numerical models of small-scale combustion systems are needed (McGrattan).
- Models of solid-phase suppression are limited by the lack of well-accepted, robust pyrolysis models that have enough physical detail to accommodate the inclusion of water impingement (McGrattan).

Structural Fire Protection

The current practice in structural fire protection in the United States is based on test methods developed a hundred years ago and test requirements based on the fire science of the 1920s. Many buildings may be significantly overprotected, while others may be unexpectedly incapable of resisting the posited fire threats. The changes in materials and construction methods over the decades have also left gaps in our fundamental knowledge of how structures perform in fire. The collapse of the two towers and Building 7 following the September 11 attacks certainly demonstrated that our understanding of structural fire protection might be incomplete for today's engineering practice. The opportunities for significant improvement in reliable and cost-effective structural fire protection are great, and there is work that needs to be done to refresh the technical basis for 21st century design. A performance-based approach to structural design for fire resistance is gradually gaining favor as an alternative to traditional prescriptive requirements such as hourly ratings and required thicknesses for fireproofing. To make performance-based methods more accessible and acceptable to practicing engineers and building officials, further research is needed, particularly in the following areas:

- A better understanding of the well-stirred reactor model, burning rate correlations, heat transfer coefficients, compartment openings, and ventilation and flame projections from windows is needed to assess fire severity for performance-based structural standards (Milke).
- The accuracy of building fuel load estimates for contemporary buildings must be confirmed (Milke).
- The high-temperature properties of structural materials, including high-strength concrete, structural steel, and fire protective coatings, must be documented (Iding).
- The performance of structural connections in fires must be better understood (Iding, Beyler).
- Analytical methods must be codified, peer-reviewed, and approved (Iding).
- Software for structural fire performance must be developed and verified (Iding).
- The role of furnace testing must be reevaluated and refined (Beyler).
- There is an urgent need to develop guidelines for assessing the fire resistance of high-performing materials in civil engineering applications (Kodur).
- There are questions about our ability to predict fire-induced structural collapse. Little research in this area has been carried out in the United States for the past two decades (Baum).

Human Behavior in Fires

The impact of fires in buildings is typically measured by their toll in deaths and injuries. These deaths and injuries are often the result of adverse interactions between people and the buildings they are trying to evacuate. This measure of impact is as much a function of how humans behave in emergency situations as it is a function of building design. Some knowledge of human behavior has been gleaned from the analysis of past disasters through survey and interview methods. The application of human factors methods also offers promise in this regard. Human response models can give a better understanding of human behavior in fire based on simulated interactions with the built environment and can lead to improved designs for notification, evacuation, and response systems. These models require different levels of input data to be able to predict the movement and/or response of people to emergency cues. Although such data are scarce and difficult to collect, human response models could prevent fires from becoming high-consequence, mass-casualty events. The prevention of a single disaster such as the West Warwick, Rhode Island, nightclub fire in February 2003 would more than justify the time and effort required for data collection and model calibration.

Workshop discussion of important research needs yielded the following insights:

- Studies should investigate the risk perceived by building occupants since September 11 and how these perceptions might change over time (Proulx).
- Studies should compare the intended response of high rise occupants during an emergency with the actual response through unannounced drills (Proulx).
- Longitudinal studies should be conducted to assess the impact of September 11th on human behavior over time (Proulx).
- Building evacuation research is needed across a wide spectrum ranging from flow and counterflow effects in stairs; effects of age and disabilities; and response to cues to decision making; training; effects of alarms; and use of elevators (Fahy).
- Research is needed to determine what levels of toxic products affect decision making (Fahy).
- Research is needed on the intersection of user needs and expectations during an emergency situation and how this impacts engineering design (Pauls/Groner).
- A number of questions from traditional human factors research apply to the emergency evacuation of buildings. Some of this work is ripe for technology transfer while other work remains to be done (Pauls/Groner).
- Complex adaptive systems that incorporate adaptive human agents in the design of performance-based fire safety systems may offer particular promise in modeling human behavior during evacuation scenarios (Pauls/Groner).

Public Policy

Fire safety in the United States is influenced to a great extent by public policy. Part of the public policy aspect of fire safety is regulation of the built environment. The regulatory system attempts to reduce risk to a level deemed acceptable by society. This presumes a political process that adopts technically informed regulations to control risk. The political process must be understood and properly integrated to achieve adequate fire safety. However, some believe that we lack the proper technical understanding and that there is little recognition of the political process by which regulation happens. Workshop participants drew attention to the following ideas:

- There is a need to further refine a risk-informed, performance-based regulatory framework that accommodates the relationship between public policy and technical issues (Meacham).
- Risk-informed, performance-based engineering and decision-making methodologies must be developed and validated (Meacham).
- Research is needed to better understand and quantify the magnitude and frequency of fire events of concern, the impact those events could have on buildings and their occupants, and overall building performance (Meacham).
- A framework is needed to link policy-level demands with technical elements, including tolerable risk (Tubbs).

- It is very hard (usually impossible) to solve a political problem with a technical solution, yet it is important to recognize that the political solution most generally will require sound science as a foundation (Kime).
- Broadly consider the criteria commonly selected for evaluating fire safety outcomes (Croce).

Data

Although "data" was not one of the original seven topics on the workshop agenda, data needs were mentioned so many times in the course of the workshop that it has been added as a separate section. The data needs to provide fire safety vary from material properties to explosion incidents to human behavior. The following are some of the data needs mentioned at the workshop:

- It is necessary to have some idea of the building contents, their distribution within the building, and their material properties (data) (Baum).
- We need an explosion incident database that contains data comparable to the data available from the NFPA and NFIRS fire databases (Zalosh).
- Without an accurate and broad-based national database, we cannot determine the success being experienced using existing explosion prevention and explosion mitigation technology and practices (Zalosh).
- Fundamental thermodynamic, thermophysical, and thermochemical property data on commercially available materials are needed to produce science-based models (Dryer, Beyler).
- There is minimal information available on material properties at elevated temperatures (Pearce).
- Data are needed to quantify the uncertainty associated with input parameters and models for conducting probabilistic fire safety assessments (Siu).
- There is a need for data on the high-temperature performance of high-performance materials (Kodur).
- Human behavior data are needed in order to design, validate, and implement building evacuation models (Fahy).
- Cost and loss data and metrics are needed to support designers, regulators, and policy makers (Meacham).
- What is needed specifically are better ways to measure accurate material property data for use in first-principle models (Croce).

OTHER TOPICS OF DISCUSSION

Other important fire safety topics were discussed at the workshop and by the committee, but since they went beyond the committee's charge they are not reported here in detail. The issue of fire-safe homes and intrinsically safe appliances was raised in the workshop by committee member Fred Dryer and others. This is an important topic because the majority of fire deaths occur in the home. The discussion revolved around the safety of consumer products how these products contribute to fires in the home and often serve as a source of ignition.

Technologies to improve firefighter capabilities and safety were of considerable interest, particularly in light of the events of September 11. The U.S. Fire Administration has submitted a report to Congress outlining a research agenda for fire service needs that was based on a workshop conducted in 1999 (USFA, 2001). Another potential research topic brought up in committee discussions was wildland fires, especially their interface with populated suburban areas. This has become a serious issue as the human population continues to encroach into areas where wildland fires are a natural and common occurrence. Such fires now displace people, cause serious damage, and place firefighters in jeopardy (of the 102 firefighter deaths recorded in 2002, 20 occurred in wildland fires (USFA, 2003)). The threat from wildland fires inspired the development of the National Fire Plan, which provided the impetus for the Joint Fire Science Program (JFSP), a collaboration between the Department of the Interior and the USDA Forest Service. The JFSP has administered and managed a large amount of fire research dealing with wildland fuel and fire management programs over the past 5 years (JFSP, 2002).

The committee decided in planning the workshop and writing this report that the topics discussed in this section, although extremely important, were not part of its charge. Robust and focused research activities are already under way to address these issues. NSF will be familiar with them and should coordinate its efforts. If NSF decides to reestablish a university grants program in basic fire research, the results of that research will certainly be of interest to those who deal with these other topics.

Interdisciplinary Research, Coordination, and Cooperation

W. J. Petak (2003) makes a strong case for a holistic to fire research similar to the approach to earthquake mitigation research. He notes that earthquake mitigation technology has advanced considerably over the years but deployment has not kept pace, even in earthquake-prone California. He believes one of the principal reasons for the gap is that earthquake risk reduction is viewed by many as a purely *technical* problem with a *technical* solution. However, despite the importance of technology, it takes institutions and people to implement workable, sociotechnical systems solutions. Figure 2.1 illustrates how the elements of such a system work together and underscores the value of interdisciplinary research that draws from the social, behavioral, and decision sciences as well as the physical sciences and engineering. For example, performance-based building codes will require realistic expectations of human behavior during a fire and must, by necessity, draw from research into human factors, the social organization of evacuation groups, and the social ties that develop within such groups.

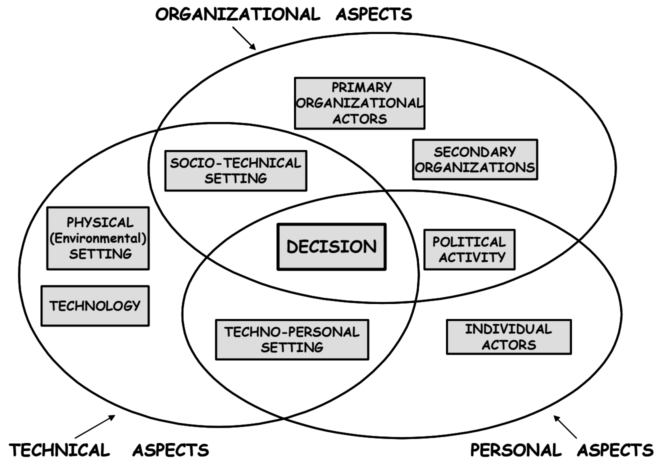

FIGURE 2.1 A sociotechnical system view for decision making (Linstone, 1984).

Presentations and discussion at the workshop also revealed the need for better coordination, cooperation, and communication among the many stakeholders in the national fire safety effort, including fire researchers and academics, the fire services, public officials, codes and standards groups, private industries, government agencies, and professional societies. Workshop participants suggested a number of possible strategies the nation could deploy for achieving this goal, including the following:

- The National Earthquake Hazards Reduction Program (NEHRP) model (Anderson),
- Use-inspired research agendas, Pasteur's quadrant (Croce),
- A national network of technology centers (Quintiere), and
- A federation of stakeholder groups with a champion (Kime, Croce, Tubbs).

Several excerpts from the workshop presentations are included to underscore this point:

- It is not clear which community owns the problem (Baum).
- Current explosion research in the United States is highly fragmented (Zalosh).
- European explosion test facilities are not only more numerous in all sizes, they are also used for integrated explosion programs with coordinated participation of government, industry, and university research laboratories (Zalosh).
- We need a coordinated university-industry-government explosion research program (Zalosh).
- It is important that a federal agency or large industrial consortium recognizes explosion protection as an important part of its mission (Zalosh).
- The Pasteur's quadrant approach to research, discussed by Croce, introduces the concept of use-inspired fundamental research and defines what should motivate all research (Dryer).
- A coordinated effort is needed between modelers, experimentalists, and manufacturers in developing detector performance metrics and accurate models for the calculation of detector responses under realistic installation conditions (Gottuk).

- There has been remarkably little interaction between researchers in the various fire communities—those involved in automatic protection, the fire service, and those in the forest fire community who are interested in the fire protection of buildings. The potential for cooperation among these various communities appears to be large (Hamins).
- A nationally coordinated network of technical centers is needed to facilitate fire safety design through education and research linked tightly to the needs of codes and standards (Quintiere).
- NSF has experience in other emerging structural engineering areas like earthquake engineering that will facilitate the process of conducting and implementing breakthrough, scientifically based engineering methods [in structural performance] (Beyler).
- A federation should be formed to identify technologies that should be adopted, to demonstrate their public value, and to generalize demonstration projects to the broader community (Kime).
- An effective stakeholder organization should be established, including a champion and societal decision makers such as the fire service and key industry, trade, and professional groups…to obtain stakeholder buy-in on key fire research directions, needs, approaches, and goals (Croce).
- A use-inspired fundamental research model should be considered (Croce).
- A group of appropriate stakeholders should be formed to help guide the process and gain acceptance for new methods in design and construction (Tubbs).
- Research priority goals, time lines, and milestones can be developed following a technology roadmap approach (Lyons).

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3

Findings and Recommendations

In accordance with its statement of task, the committee has developed a number of findings and recommendations. It should be noted that these findings and recommendations are based on the knowledge and experience of the committee members and discussions facilitated by the workshop held on April 15-16, 2002. Although the participation of the workshop attendees was invaluable for the preparation of this report, the findings and recommendations represent the opinions of the NRC committee that was appointed for this purpose. The responsibility for the final content of the report rests entirely with this committee and the National Research Council.

FINDINGS

The High Cost of Fire. Unwanted and preventable fire in the United States continues to exact an unacceptably high cost in terms of human suffering and economic losses. The threat to people, property, and economic activity is neither well understood nor fully appreciated by policy makers and the public at large.

Benefits of Performance-Based Practices. Performance-based building codes, which are now available in the United States for adoption by state and local governments, offer real promise for regulators and public officials to institute regulations that reflect a better understanding of risks and improved safety performance for buildings in their communities. However, performance-based codes depend on the ability of engineers to predict how buildings will perform under fire conditions. There are significant gaps in the data and knowledge base needed to support performance-based codes, engineering tools, predictive models, and risk assessment.

Insufficient Funding. The current funding levels and organizational infrastructure for fire research in the United States are inadequate to address even the most fundamental research needs that were raised at the workshop and subsequently discussed by the committee. The documented costs of unwanted fire, in both human and economic terms, justify substantial investment in fire safety research and the development and deployment of the products of that research. The public at large, businesses, institutions, and government agencies can all benefit from better safety at less cost.

Coordination and Cooperation. Improving fire safety in the United States depends on the combined efforts of a range of disciplines and communities, from fire researchers and academics to the fire services, public officials, codes and standards groups, private industry, government agencies, and professional societies. There is a need for better communication, cooperation, and integration of national fire safety efforts.

Important Role for Universities. University-based fire research has all but evaporated in the United States over the past three decades. In addition to choking off new scientific discovery, this turn of events has all but eliminated the production of young scholars with a career commitment to inquiry and teaching in the fire safety sciences.

Role of the National Science Foundation. The NSF has traditionally served as an incubator for coordinated, interdisciplinary research programs for hazard reduction that involve the university research community, government agencies, and the private sector. As compared with more mission-oriented agencies, an NSF commitment can be particularly beneficial in areas of basic research that will improve our understanding of the nature of fire; its detection, suppression, and control; technology applications (e.g., next-generation residential smoke detectors, material coatings, and intrinsically safe home appliances); human behavior; and interdisciplinary studies to better inform building codes, design, and regulatory/public policy processes.

The National Earthquake Hazards Reduction Program Model. Through NEHRP, the U.S. government has aggressively pursued such an integrated approach for addressing the earthquake hazard. Its approach has resulted in greatly improved building performance and reduced levels of injury and death.

RECOMMENDATIONS

The committee's recommendations are not intended to address all areas of fire safety or even all areas of fire research. They are targeted specifically to those areas where the committee believes the National Science Foundation could have a significant positive impact on the state of fire research that would enhance fire safety in the United States and are intended to suggest a path forward for NSF.

> **1. NSF should reestablish and fund a program in basic fire research and interdisciplinary fire studies. Funding of approximately $10 million per year is recommended to begin this effort. This initial funding level would restore the NSF investment in fire research to its 1973 level (in today's dollars). It should be reconsidered once a robust research infrastructure is in place.**

The level of fire research at U.S. universities has declined greatly since the RANN program was terminated at NSF. Given NSF's charter to support basic research and education, the committee believes that NSF is the appropriate agency for administering a reinvigorated and robust university grants program in fire research. Funding of university principal investigators and graduate students needs to be emphasized, both to accomplish research goals and to invest in the nation's next generation of investigators and teachers—the human capital so necessary for continuous improvement in fire safety. There are many on-going initiatives and programs within NSF (e.g., nanotechnology, sensors, high-performance materials, surface chemistry, human and social factors in hazard mitigation, structural system performance) that could provide a logical nexus (not to speak of existing funding) for reestablishing a comprehensive and interdisciplinary focus on fire safety within NSF.

This report makes no attempt to suggest a national research agenda or to identify fire research priorities for the nation. Such prescription was beyond the scope of this effort. The committee believes that work previously done by others, such as the SFPE Research Agenda 2000, the United States Fire Administration (USFA), and the Joint Fire Science Project (JFSP), along with the discussion of topical areas found in this report, will serve as a valuable resource for evaluating initial research proposals. In the short term, NSF can make use of this report and recent work by others to evaluate research proposals. The committee believes that the recommended funding level of $10 million annually would be an appropriate starting point for supporting multiple investigators in the physical, social, and behavioral sciences and engineering, with an emphasis on fostering interdisciplinary activities. In the longer term, NSF should coordinate its efforts with other agencies to build an integrated and robust research infrastructure for fire safety. Once such an infrastructure is in place, higher funding levels (such as those recommended in *America Burning*—approximately $113 million in today's dollars) should be considered. The committee would note that significant resources are already available through the multiplicity of mission-directed fire safety activities currently under way in federal agencies. Better coordination of existing fire safety planning, research, and implementation and their integration under a renewed initiative by NSF could create significant opportunities to leverage research dollars, increase technology transfer, and speed deployment of new methods and products.

2. A coordinated national attack to increase fire research and improve fire safety practices should be launched. The committee recommends that NSF support exploratory activities to determine if a model such as NEHRP or any other model that combines integration, cooperation, stakeholder involvement, and collaboration in research could hasten the development and deployment of improved fire safety practices through more coordinated, better targeted, and significantly increased levels of fire research in the United States.

Many workshop participants emphasized that, in addition to addressing the paucity of basic research, there also needed to be better coordination, cooperation, and communication among the stakeholders in national fire safety. The United States lacks an adequately funded and well-coordinated national fire research program such as that for earthquake engineering embodied in the NEHRP. Most federally funded fire research is mission-focused and conducted by user agencies, which show little interest in leveraging the research investment, supporting graduate students, or transferring technology. Given the emergence of performance-based design and regulatory practices, the fire safety field is desperately in need of integrated research findings targeted to the priority needs of practice. A number of possible national strategies for achieving this goal were discussed at the workshop. The committee believes that a national attack on the U.S. fire problem requires interdisciplinary communication, cooperation, and coordination supported by adequate funding. The earthquake safety movement, which began in the 1970s and has evolved into the successful NEHRP is an excellent model for the fire safety community to consider. An effort modeled on the NEHRP could engage all federal agencies currently involved with fire safety and, at a minimum, should link a reinvigorated NSF university grants program with the valuable efforts currently under way at other agencies, such as the National Institute of Standards and Technology and the U.S. Fire Administration.

APPENDIXES

Appendix A

Biographies of Committee Members

David Lucht, *Chair,* is a professor and the director of the Center for Fire Safety Studies at Worcester Polytechnic Institute. Professor Lucht began his career in Ohio, and he worked as an engineer and researcher at the Ohio State University. He went on to become the Ohio State Fire Marshal. After Congress passed the Federal Fire Prevention and Control Act in 1974, he became the first presidential appointee at the newly created U.S. Fire Administration under President Gerald Ford. He became the deputy administrator of USFA in 1975 and served until 1978. Professor. Lucht then went on to establish the first master's degree program in fire protection engineering at WPI in 1978. He is currently on the board of trustees of Underwriters Laboratories, Inc., and has been a member of NFPA's board of directors. Professor Lucht graduated with a B.S. in fire protection and safety engineering from the Illinois Institute of Technology and holds professional registration as an engineer in the state of Massachusetts. He is a fellow and past president of the Society of Fire Protection Engineers.

Craig Beyler is the technical director for Hughes Associates, Inc. He is recognized for his unique leadership in developing and implementing scientifically based methods for engineering analyses of fire phenomena. His many contributions to this area have included both theoretical and experimental work in enclosure fire phenomena and extinguishment mechanisms. Of particular relevance is his work on an analytical basis for fire detector response, SFPE´s Practice Guide on Radiation from Pool Fires, and his advancements of heat/smoke vent engineering calculation methods. Recently he received the Arthur B. Guise Medal recognizing eminent achievement in advancing the science of fire protection engineering and was elected as an SFPE fellow. Dr. Beyler holds a B.S. degree in fire protection engineering from the University of Maryland, a B.S. in civil engineering from Cornell, an M.S. in mechanical engineering from Cornell, an M.Sc. in fire safety engineering from the University of Edinburgh, and a Ph.D. in engineering science from Harvard.

David Collins is president of the Preview Group, Inc., in Cincinnati, Ohio, and manager of the American Institute of Architects' (AIA's) Code Advocacy Program. Mr. Collins has worked as regional code manager for the American Forest and Paper Association and the Portland Cement Association, as well as deputy chief building official for Hamilton County, Ohio. He is a member of BOCA, ICBO, and SBCCI as well as NFPA and serves on numerous ICC and NFPA committees. He has been on many AIA national committees and served as AIA secretary. Mr. Collins has an AAS in architecture from Purdue and a B.S. in architecture from University of Cincinnati. He is a registered architect, a certified building official, and a certified plans examiner in the State of Ohio.

Fred Dryer is a professor of mechanical and aerospace engineering at Princeton University. Dr. Dryer's principal research interests are in the fundamental combustion sciences, with emphasis on the chemistry and chemical kinetics of fuels and hazardous waste materials as related to ignition, combustion, and emissions generation and abatement; the fundamentals of formation, ignition, secondary atomization, and liquid-phase chemistry of conventional and synthetic fuel droplets as related to heavy industrial fuel combustion and emission control, gas turbine/reciprocating engines and liquid fuel fire safety-related issues on earth and in microgravity environments; and solid-phase and gas-phase interactions as related to particle burning phenomena and materials processing. Dr. Dryer recently served on two National Materials Advisory Board/National Research Council committees—the Committee on Improved Fire and Smoke Resistant Materials for Commercial Aircraft Interiors and the Committee on Aviation Fuels with Improved Fire Safety—on the NASA Scientific Advisory Panel for the Atmospheric Effects of Aviation Project, and on the National Materials Advisory Board/National Research Council. He received a bachelor's degree in aeronautical engineering from Rensselaer Polytechnic Institute and a Ph.D. in aerospace and mechanical sciences from Princeton University. He also served on the professional research staff in the Mechanical and Aerospace Engineering Department of Princeton University for 8 years.

Ken Dungan is president and cofounder of Risk Technologies, LLC, and chair of the SFPE's Scientific and Educational Foundation. Mr. Dungan served as department head of the Fire Protection Engineering Division at Union Carbide's Oak Ridge gaseous diffusion plant. He also was assistant director of engineering services for Verlan, Ltd., an insurance company for the coatings industry. Mr. Dungan then founded Professional Loss Control, Inc., in 1976, specializing in safety, fire protection, and environmental engineering. In 1995, he cofounded Risk Technologies and Performance Design Technologies, LLC. He is a past president of the SFPE and past chair of the American Association of Engineering Societies. Mr. Dungan is serving on many NFPA committees, is a member of the American Institute of Chemical Engineers, and is a licensed engineer in Pennsylvania and Tennessee.

Ofodike "DK" Ezekoye is associate professor and General Motors Centennial Teaching Fellow in mechanical engineering at the University of Texas at Austin. Dr. Ezekoye has worked on problems such as heat transfer in combustion systems, aerosol generation and filtration, and inverse design of thermal systems. He joined the University of Texas faculty in 1993 after a year as an NRC postdoctoral research fellow at the Building and Fire Research Lab at NIST. Dr. Ezekoye has published more than 70 technical articles and reports. He received a National Science Foundation CAREER Award in 1997. Dr. Ezekoye has a B.S. in mechanical engineering from the University of Pennsylvania and an M.S. and a Ph.D. in mechanical engineering from the University of California, Berkeley.

William Feinberg is professor emeritus of sociology at the University of Cincinnati and an experienced researcher of crowd behavior during fire disasters. He has been the chair of the sociology and computers section of the American Sociological Association and has been active in the ASA for over 35 years. His research has led to a computer simulation model called FIRESCAP, which simulates human reaction to a fire alarm. Dr. Feinberg has an A.B. in sociology, an A.M. in sociology, and a Ph.D. in sociology, all from Brown University.

Charles H. Kime is an assistant professor at Arizona State University, East Campus. He coordinates the fire services programs in the College of Technology and Applied Sciences; these include a bachelor of applied science degree in fire service management and a master of science in technology degree in fire service administration. Prior to joining Arizona State University, Dr. Kime spent more than 32 years with the Phoenix, Arizona, fire department, retiring in 1999 as the executive assistant fire chief. In the fire services, his experiences range from line firefighting positions to supervisory and middle management, then to executive management positions, which he held for more than 20 years. During his fire services career, Dr. Kime was very active in university education. He has taught in the graduate program of the Arizona State University School of Public Affairs and the bachelor of interdisciplinary studies degree program at the same institution, as well as myriad fire sciences and fire services administration classes. His research interests include organizational leadership, organizational behavior, and human resource management, especially within the context of the fire service. Dr. Kime holds a bachelor's degree in industrial technical education, an M.B.A., and a Ph.D. in public administration. His book *Organizational Leadership: Fire Services in the United States* was published in 2001 by Elsevier.

John Lyons (NAE) is a retired director of the U.S. Army Research Laboratory (ARL) and a former director of NIST. He was elected to the National Academy of Engineering in 1985 "for outstanding contributions to fire science and technology." Dr. Lyons helped create and launch the Advanced Technology Program and the Manufacturing Extension Partnership at NIST and the Federated Laboratory program at ARL. His particular interests are managing multiprogram laboratories, movement and diffusion of technologies, formation and management of partnerships between government labs and the private sector, stimulating consortia formation and management, technology and competitiveness, measuring research performance, justifying research efforts, and managing technical personnel. Dr. Lyons' career spans almost 20 years in the chemical industry and 25 years in government labs. The result is a broad perspective useful in today's environment of sharing and partnering between the public and private sectors.

Fred Mowrer is an associate professor at the University of Maryland. He joined the faculty of the Department of Fire Protection Engineering in 1987 after receiving his Ph.D. in fire protection engineering and combustion science from the University of California, Berkeley. Dr. Mowrer received a B.S. degree in fire protection and safety engineering (1976) from the Illinois Institute of Technology and an M.S. degree in engineering (1981) from the University of California, Berkeley. He is a registered fire protection engineer in California. He has worked as a consultant for an international fire protection engineering firm and as an engineering representative for an insurance organization. Dr. Mowrer is recent past president of the Society of Fire Protection Engineers and an active member of the International Association of Fire Safety Science and the National Fire Protection Association. He currently serves on the board of directors of the Society of Fire Protection Engineers. Dr. Mowrer's primary research interests include measurement of the contribution and response of products and materials to fire, mathematical fire modeling, development of a computer-based framework for building fire safety analysis and design, and analytical fire reconstruction. Dr. Mowrer has published papers on all these topics. He received the Harry C. Bigglestone Award for excellence in written communication of fire protection concepts from the NFPA on three occasions.

Eli Pearce is university research professor at Polytechnic University in New York, where he has served as a member of the faculty and administrator since 1971. From 1958 to 1973, he worked in industry, at DuPont, J.T. Baker Chemical Co., and Allied Chemical Corporation. Dr. Pearce received a B.S. degree from Brooklyn College (1949), an M.S. from New York University, and a Ph.D. from the Polytechnic Institute of Brooklyn (1958). His research interests are in polymer science, including synthesis, structure-property relationships, degradation, flammability, and polymer compatibility. He was president of the American Chemical Society through the year 2002.

Judy Riffle is a professor of chemistry at the Virginia Polytechnic Institute and State University (Virginia Tech) and director of its macromolecular science and engineering program. She has worked for Union Carbide as a research chemist and served as vice president for R&D at Thoratec Laboratories Corporation, a cardiovascular biomaterials company. In 1988, Dr. Riffle became assistant professor of chemistry at Virginia Tech, where she holds a tenured position. She has served as chair of the Polymers Division of the American Chemical Society. Her research has been on new polymeric materials and modifications of old polymeric materials that are flame retardant. She is active in integrating research and education through the Macromolecular Science and Engineering Program. Dr. Riffle has a B.S. in chemistry and a Ph.D. in polymer chemistry, both from Virginia Tech.

James T'ien is professor in the Department of Mechanical and Aerospace Engineering at Case Western Reserve University. He also serves as the chief scientist on combustion for the National Center for Microgravity Research on Fluids and Combustion. He has performed fundamental combustion research in a number of topics, including flame spread over solids, material flammability, and flame-radiation interaction. He is the recent recipient of a NASA public service medal for his contribution to microgravity combustion and spacecraft fire safety. Dr. T'ien received a B.S. from National Taiwan University, an M.S. from Purdue, and a Ph.D. from Princeton.

Beth Tubbs is a staff engineer at the International Conference of Building Officials, where she administers the code development process, code maintenance, and interpretation for the Uniform Building Code and Uniform Fire Code as a representative of the International Fire Code Institute. She is closely involved in code development committees, including the Secretariat of the International Fire Code and International Building Code Performance Committees, providing building and fire code technical support and assisting with related educational activities as well as acting as a liaison with other national agencies on fire protection issues. She has degrees in civil engineering and fire protection engineering from Worcester Polytechnic Institute and is a licensed professional engineer in fire protection engineering in California.

Forman Williams (NAE) is professor of engineering physics and combustion and director of the Center for Energy Research at the University of California, San Diego. He was elected to the National Academy of Engineers, Sec. 01 Aerospace Engineering, in 1988 "for contributions to the advancement of combustion and flame theory." Before his present position, Dr. Williams taught at Harvard and Princeton. His field of specialization is combustion, and he is the author of *Combustion Theory* (Addison-Wesley, 2nd ed., 1985) and the coauthor of *Fundamental Aspects of Combustion* (Oxford, 1993). He is a member of the editorial advisory boards of *Combustion Science and Technology*, *Progress in Energy*, the *AIAA Journal*, *Combustion Science,* and *Archivium Combustionis*. Dr. Williams is currently researching many fundamental aspects of combustion, as well as combustion in microgravity. He received a B.S. from Princeton and his Ph.D. from the California Institute of Technology.

Tom Woodford is an associate professor and head of the Department of Fire Protection and Safety Engineering Technology at Oklahoma State University. He spent 12 years in the U.S. Navy, specializing in surface ship damage control and engineering. He also spent 2 years with an independent fire-testing laboratory in Washington State, where his responsibilities included work in large-scale fire testing and computer fire modeling. Mr. Woodford is an associate member of the Society of Fire Protection Engineers and the International Association for Fire Safety Science and a member of the National Fire Protection Association. He received a bachelor's degree in electrical engineering from the University of Virginia in 1983, a master of science degree in ocean engineering from the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution in 1991, and a master of science in fire protection engineering from the University of Maryland in 1996.

Appendix B

Workshop Agenda

WORKSHOP TO IDENTIFY INNOVATIVE RESEARCH NEEDS TO FOSTER IMPROVED FIRE SAFETY IN THE UNITED STATES

April 15-16, 2002
Washington, D.C.

MONDAY, April 15

8:00 a.m. *Continental Breakfast*

8:30 **Welcoming Remarks: Workshop Objectives and Agenda**

Richard G. Little, Director, Board on Infrastructure and the Constructed Environment

David A. Lucht, Chair, Committee to Identify Innovative Research Needs to Foster Improved Fire Safety in the United States, Wochester Polytechnic Institute

Peter Chang, National Science Foundation

8:45 **Fire Safety Issues in the United States—an Overview**

John Lyons, Director, U.S. Army Research Lab (retired)

9:30 **Earthquake Engineering—A Possible Model of Success for Fire Safety Engineering**

William Anderson, National Research Council

10:00 *Break*

10:30 **Fire and Explosion Issues**

Moderator: Fred Dryer, Princeton University

Simulation of Building Fires—Howard Baum, NIST

Explosion Phenomena—Bob Zalosh, WPI
Flammability of liquids and gases—Fred Dryer, Princeton

11:15 **Moderated Panel Discussion**

12 noon *Lunch (in meeting room)*

1:00 **Materials and Retardant Issues**

Moderators: Eli Pearce, Polytechnic University

Performance of Polymer and Composite Materials—Judy Riffle, Virginia Polytechnic Institute, Jack Lesko, Virginia Polytechnic Institute
Possibilities for Fire Retardant Materials—Ed Weil, Polytechnic University
Thermal Decomposition of solids—Takashi Kashiwagi, NIST

2:00 **Moderated Panel Discussion**

3:00 *Break*

3:15 **Fire Protection Systems**

Moderator: Ken Dungan, Risk Technologies, LLC

Fire Signatures—Dan Gottuk, Hughes Associates
Alternate Sensors—Susan Rose-Pehrsson, NRL
Suppression—Anthony Hamins, NIST

4:00 **Moderated Panel Discussion**

5:00 *Recess for the day*

TUESDAY, April 16

8:00 a.m. *Continental Breakfast*

8:30 **Fire Protection Engineering Tools**

Moderator: Fred Mowrer, University of Maryland

Deterministic Models—Jim Quintiere, UMD
Probabilistic Methods in Deterministic Models—Nathan Siu, USNRC
Suppression Models—Kevin McGrattan, NIST

9:15 **Moderated Panel Discussion**

10:00 *Break*

10:30 **Structural Performance Issues**

Moderator: Craig Beyler, Hughes Associates, Inc.

Fire Severity—Jim Milke, UMD
Structural Dynamics—Bob Iding, WJE
High Performance Materials—Venkatesh Kodur, NRC Canada

11:15 **Moderated Panel Discussion**

12 noon *Lunch*

12:30 p.m. **Human Behavior Issues**

Moderator: William Feinberg, University of Cincinnati

Understanding Human Behavior in Stressful Situations—Guylene Proulx, NRCC
Available Data and Input into Models—Rita Fahy, NFPA
Human Factors Contributions to Building Evacuation Research and Systems Design: Opportunities and Obstacles—Jake Pauls/Norman Groner

1:15 **Moderated Panel Discussion**

2:00 **Public Policy Issues**

Moderator: Beth Tubbs, International Conference of Building Officials

Risk and Data Needs for Performance-based Codes—Brian Meacham, ARUP
Fire Service Perspective—Chuck Kime, ASU
Research to Practice—Paul Croce, FM

2:45 **Moderated Panel Discussion**

3:30 **Smart Growth for Fire Safety**

What are big opportunities for breakthroughs in research?
What kind of impact will they have?

What are the keys need in education, training, and technology transfer?
What is the role of NSF and other agencies and institutions?

5:30 *Adjourn*

Appendix C

Workshop Attendees

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Appendix D

Workshop Background Papers

Baum, Howard. Simulating Enclosure Fire Dynamics.

Beyler, Craig. Structural Fire Protection.

Croce, Paul. Public Policy Issues: Bringing Research Into Practice.

Fahy, Rita. Available Data and Input Into Models.

Gottuk, Dan. Fire Signatures and Detection.

Hamins, Anthony. Fire Suppression.

Iding, Robert. Performance-Based Structural Analysis To Determine Fireproofing Requirements: Methodology, Case Studies, And Research Needs.

Kashiwagi, Takashi. Research Needs For Flammability Of Polymeric Materials.

Kime, Charles. Transferring Fire Safety Technology Research from Academia to Practice: A Public Policy Issue at the Local Level.

Kodur, Venkatesh. Fire Resistance Research Needs For High Performing Materials.

Lyons, John. The Fire Problem.

McGrattan, Kevin. Large-scale Modeling of Fire Suppression With Water Sprays.

Meacham, Brian. Risk and Data Needs for Performance-Based Codes.

Milke, James. Research Needs For Assessing The Fire Severity In Performance-Based Fire Resistance Analyses.

Mowrer, Frederick. Fire Protection Engineering Tools.

Pauls, Jake, and Norman Groner. Human Factors Contributions To Building Evacuation Research And Systems Design: Opportunities And Obstacles.

Proulx, Guylene. Understanding Human Behavior in Stressful Situations.

Quintiere, James. Deterministic Models for Fire Protection Engineering.

Riffle ,Judy, and Jack Lesko. Polymer Matrix Composite Constitutive Properties, Evolution & Their Effects on Flame Durability & Structural Integrity.

Rose-Pehrsson, Susan. Fire Protection Systems: Alternative Sensors.

Siu, Nathan. Probabilistic Methods in Fire Safety Assessment: Potential Research and Development Needs.

Weil, Ed. Possibilities for Fire Retardant Materials-Toward Solving the Most Difficult Problems.

Zalosh, Robert. U.S. Explosion Research and Education Needs.

RISK AND DATA NEEDS FOR PERFORMANCE-BASED CODES

Brian J. Meacham[1]

ABSTRACT

The transition to performance-based codes is underway in the United States. For many on the technical side of the equation, this is a positive move, as a performance environment promises greater opportunities to apply analytical tools and methods to develop cost effective fire protection for buildings. For many on the policy setting side of the equation, however, the move to performance is being met with concern, as the certainty in design requirements provided by prescriptive regulation will no longer be assured, and the tools and data seem to be lacking to ensure that performance-based designed buildings will maintain levels of risk deemed tolerable to society. To gain a acceptable level of comfort for all involved, significant investment will be required (1) to further refine the risk-informed performance-based building regulatory framework, (2) to develop and validate risk-informed performance-based engineering and policy decision-support methodologies, (3) to develop baseline performance and risk data and databases, and (4) to provide training and education for those working in all aspects of the built environment.

Introduction and Background

The U.S. building and fire communities first seriously began to consider performance-based regulation and design in the early 1990s. A significant catalyst was the 1991 conference, Firesafety Design in the 21st Century, supported by the National Science Foundation and the Society of Fire Protection Engineers (SFPE), and hosted at Worcester Polytechnic Institute (Lucht, 1991). Through presentations and breakout group discussion, the conference participants identified goals, barriers and strategies for fire safety design in the 21st century. The outcomes included a United States national goal that "by the year 2000, the first generation of an entirely new concept in performance-based building codes be made available to engineers, architects and authorities having jurisdiction... in a credible and useful form." The primary barrier to achieving this goal was identified as a lack of fire safety goals aimed at establishing a level of safety acceptable to the public. As the conference report states (Lucht, 1991):

> "All four breakout groups identified the lack of design goals as a leading barrier to the use of emerging firesafety design methods. Each group used different words, but drove at the same point: lack of definition of desired level of safety, absence of established uniform levels of risk, lack of measurements for success/acceptability of risk, lack of performance-based objectives. Again and again, it was noted that current codes and standards do not specify the overall level of safety each is trying to achieve in the public interest. This is analogous to having sophisticated structural analysis and design methods available to structural engineers without any idea as to the live loads, dead loads or safety factors that have been established as design criteria."

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Recognition of the need to incorporate specific goals and objectives into the regulations, which reflect acceptable or tolerable levels of risk/performance, was an important step. However, the process of incorporating these concepts is a challenge, as the concepts of risk and acceptable risk, and the use of risk analysis, are not uniformly understood or widely accepted throughout the building and fire communities. This is true for many reasons, including a poor understanding of what the magnitude of "actual" risks are, a shortage of quantified risk values that are widely accepted, and a poor understanding of the likelihood of unforeseen or "improbable" events occurring in any given building. As reported in a National Research Council supported study (McDowell and Lemer, 1991):

> "Lacking a common framework for discussion and analysis of safety, the public and government officials are often poorly prepared to deal effectively with issues that have small probabilities of occurrence and the potential for severe consequences. Development and broad application of risk analysis procedures will help facility professionals, policy makers responsible for assuring safety, and the people and property owners exposed to risk to understand more clearly the nature of those risks and to determine what levels of risk are socially and economically tolerable."

This observation highlighted another significant concern: in the early 1990s, building and fire communities lacked a common framework or process for identifying, addressing, and incorporating risk concepts into the regulatory system.

Research and Development: The Society of Fire Protection Engineers

Following the 1991 conference at WPI, the SFPE embarked on three major efforts aimed at addressing the above issues: research into performance-based design (Meacham, 1998), research into the use of risk concepts in performance-based regulation (Meacham, 2000), and the development of an engineering guide to performance-based design (SFPE, 2000). Although advancements were made through these efforts, additional needs were also identified (Meacham, 1999). This need for research motivated the SFPE to hold a workshop aimed at establishing a research agenda for fire protection engineering (SFPE, 2000a), and to co-sponsor both a United Engineering Foundation (UEF) workshop on a similar topic (Cox, 2001) and another NSF sponsored conference at WPI (Lucht, 2001). All of these efforts identified several recurring needs, including (from Meacham, 1999):

1. There is a need to consider the level(s) of tolerable risk (personal and societal).
2. There is a need for clear specification of, and agreement to, fire safety goals and objectives, and performance and design criteria.
3. There is a need to understand how fire initiates, develops and spreads.
4. There is a need to understand how various fire safety measures (active and passive), including fire department operations, can mitigate potential fire losses.
5. There is a need to understand how people react in a fire situation.
6. There is a need to have, and to apply credible data, tools and methodologies in the determination of the above factors.
7. There is a need to consider the financial impact of fire safety decisions.
8. There is a need to address uncertainties in the analysis and design process.

Research and Development: The Code Development Community

The U.S. code development community began the transition to performance-based codes following the 1991 WPI conference as well, with the formation by the International Code Council (ICC) of the Performance Code Committee in 1996, and with the National Fire Protection Association (NFPA) initiating an effort to add a performance option to the *Life Safety Code*® (Watts, 1997). In addition, the ICC and the NFPA recognized the need to address data and risk issues for performance regulation, and supported research into risk in performance regulations (Meacham, 2000) and supported the SFPE in development of fire protection engineering design guidance.

In 2000, the National Fire Protection Association published NFPA Standard 101, the *Life Safety Code,* with a performance option (NFPA 101, 2000). In 2001, the International Code Council published the *ICC Performance Code for Buildings and Facilities* (ICC, 2001). Both of these performance-based codes focus on "policy level" objectives, and refer to standards, guides and practices of professional organizations, such as the SFPE, for performance criteria, analysis, design, testing, and evaluation methods.

However, like the SFPE, the ICC and the NFPA recognized that gaps exist in data and methodologies for performance regulation, and participated in the workshops sponsored by the SFPE described above. In addition, each organization has participated in international committees and task groups aimed at sharing information and defining needs for performance regulation. The two primary such groups are the Inter-jurisdictional Regulatory Collaboration Committee (IRCC) and the International Council for Building Research and Innovation (CIB), Task Group 37. Recent papers by members of the IRCC and CIB TG37 reflect the needs of the regulatory community in terms of an overall framework, performance criteria (data), risk, and linkages (e.g., Bergeron et al., 2001; Beller et al., 2001; Bukoswki et al., 2001; Meacham, 2001; Meacham et al., 2002). These issues will be discussed in more detail later in this paper.

Risk and Data Research Needs

Even though the US has achieved the 1991 goal of developing performance-based building and fire regulations, it is widely agreed that there remains a need for a more comprehensive risk-informed performance-based regulatory framework, for risk, decision and cost analysis methodologies, and for data to support performance-based building and fire regulations. These needs are especially important from the policy perspective, for if the system is to be supported by policy makers and the public, there must be confidence in the data, tools, and methods being applied, and in the decisions that are made based on risk tolerability, performance levels, and cost.

Refined/Modified Risk-Informed Building Performance-Based Regulatory Framework

One of the key elements of understanding that has been provided by the IRCC has been the need to appropriately recognize the relationship between policy issues and technical issues. The technical community needs to understand they are working within a larger system, which must ultimately relate to qualitative goals and functions of buildings. In trying to communicate this concept, the IRCC has outlined a risk-informed performance-based regulatory model (Meacham et al., 2002). This model can conceptually be divided into two portions, qualitative and quantitative. The qualitative portion is often where the goals, functions and level of performance are described. This portion of the model sets the structure and focal point for the quantitative portion of the model. It should be noted that the qualitative portion of this model recognizes that a performance system is only useful if quantitative methods and solutions are provided. The key to the model is that quantitative methods and solutions must be specifically linked to the qualitative portion of the model to complete the system.

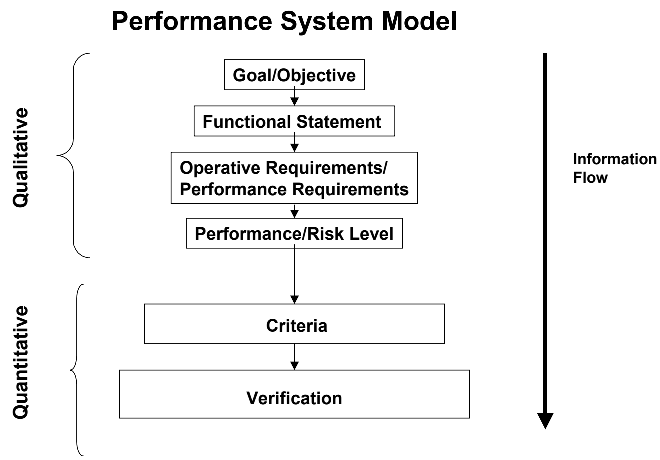

Figure 1. Outline of IRCC performance model (Meacham et al., 2002).

The intent is that the model can be viewed from the top down or the bottom-up. In other words, one should be able to start with a goal statement and be able to ultimately link to a specific quantitative requirement. Inversely, one should be able to look at a specific quantitative requirement and link to a top-level qualitative goal. If such linkages cannot be made then there is a disconnect. Generally, it should be remembered that the top-level policy/user need oriented portion of the model sets the scope for the quantitative portion.

Linking Societal Objectives, Risk Tolerability, Data, Methods, and Solutions

When designing and constructing a building, quantitative, measurable methods and solutions must be used. In the past, such methods have been available in the form of prescriptive codes, standards and design approaches. These approaches have generally been successful, but key linkages were missing (Meacham et al., 2002). Without the qualitative level, the full scope and intent of what a building code, a standard, or even a specific design provides is unknown to society, public policy makers, building owners and users. This makes it difficult to justify new and innovative approaches since it is difficult to determine what is expected. In order for the performance approach to be effective, tools are necessary which link society, policy makers, building owners and users, and the technical community. An example of the necessary linkages is illustrated in Figure 2 below, which helps to illustrate the data needs (risk and other). The desired levels of tolerable risk lead to descriptions of desired performance. To achieve desired performance, one needs to know the metrics, and needs to have test, measurement, prediction, and calculation methods to assess when the desired performance has been reached. Thus, performance criteria need to be developed within the performance framework and not in isolation.

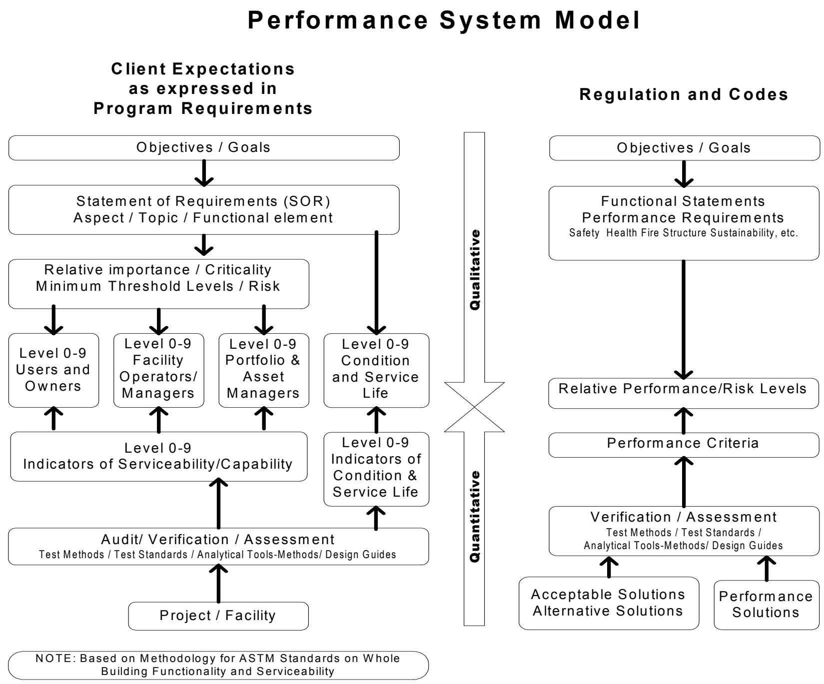

Figure 2. Linkages between qualitative and quantitative criteria (Meacham et al., 2002).

The need for the linkages outlined in Figure 2 can be further seen by going into more detail, as illustrated in Figure 3 below.

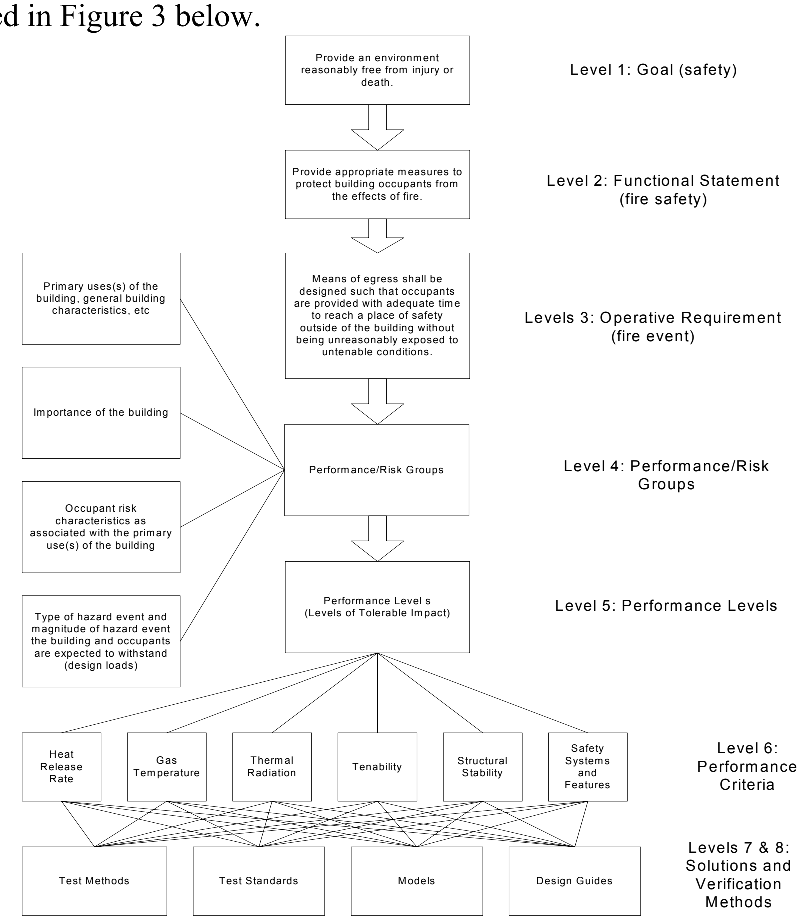

Figure 3. Relationship between components of performance system (Meacham, 1999a).

Figure 3 is a powerful visual tool for understanding just how much additional research is needed to operate successfully in a performance system. It illustrates how much data are needed to make the linkage from a goal of "safety," described in terms of "tenable conditions," to the metrics used to define, measure, construct, and evaluate buildings and building components to provide the desired level of performance and safety. *Development of test methods, standards, guides, analytic methods, and data – outside of a clear regulatory framework – leaves the door open for confusion, rather than consensus, as the linkages required to demonstrate that the necessary connections have been made may not exist*.

Events, Impacts and Performance

As part of the above stated need to link qualitative goals and quantitative methods and metrics for fire regulation, further research is needed into understanding and quantifying the fire events of concern, the impact those events could have on buildings and occupants, and the overall building performance. As illustrated in Figure 4, a mechanism for discussing these concepts for performance-based regulation has been outlined and implemented (Meacham, 2000; ICC, 2001). Performance Groups contain buildings of different uses for which similar levels of performance are desired (e.g., Performance Group I includes small unoccupied out buildings, and Performance Group IV includes critical facilities). The Levels of Tolerable Impact reflect an expectation of building performance given a specific Magnitude of Design Event (e.g., a Very Large fire is expected to result in no more than Moderate damage to a Performance Group IV building, while it is expected to result in severe damage to a Performance Group I building).

	LEVELS OF TOLERABLE IMPACT			
MAGNITUDE OF DESIGN EVENT	Performance Group I	Performance Group II	Performance Group III	Performance Group IV
VERY LARGE (Very Rare)	SEVERE	SEVERE	HIGH	MODERATE
LARGE (Rare)	SEVERE	HIGH	MODERATE	MILD
MEDIUM (Less Frequent)	HIGH	MODERATE	MILD	MILD
SMALL (Frequent)	MODERATE	MILD	MILD	MILD

Figure 4. Relationship between events, tolerable impacts and building performance (adapted from Meacham, 2000; ICC, 2001).

Those familiar with seismic engineering will recognize the above, as it is derived from concepts developed by groups such as the Structural Engineers Association of California (Hamburger et al., 1995; SEAOC, 1998). Modified and incorporated into the *ICC Performance Code for Buildings and Facilities* to apply to multiple hazards (ICC, 2001; Meacham, 2000), however, *the concept has shortcomings for fire safety, as it does not adequately quantify* *magnitude and frequency of events because the required data are not currently available. Unlike a natural hazard event, fire does not impact a structure uniformly, and its impact is dependent on the structure, its protection features and its contents. Key questions include: how should fire loads be defined, how should probability of occurrence be characterized, and how can the fire loads be regulated?* Should "worst credible event" scenarios be employed, and if so, who decides what those scenarios are? Alternatively, should sets of baseline "design fire loads" be developed for specific occupancy types, building configurations, and occupant loadings? The latter more closely relates to the development and use of structural loads, and can be linked to tolerable risk and performance levels. This is an area that, as the performance concept moves forward, requires significant attention.

Development of Risk-Informed Decision Tools and Methods

To support the above effort, and to support regulatory developers, design professionals, and enforcement officials, it is becoming increasingly important to develop risk-informed decision methods and tools to help balance the critical risk, benefit and cost components. Development of a comprehensive fire risk, benefit and cost model will have to consider several factors, including how risk is defined, who is impacted and how, and how benefits and costs are to be measured (e.g., see Meacham, 2000; Notarianni, 2000).

This need for risk-informed approaches is not new. In 1972, the U.S. General Services Administration and the U.S. National Bureau of Standards jointly developed an event logic diagram that showed alternative approaches to achieving building fire safety (Meacham, 1998a). After several revisions, this tree eventually became the basic reference guide of the GSA's goal-oriented systems approach to building fire safety. Described in a document commonly referred to simply as *Appendix D,* the approach became a basis for describing a risk-informed systems approach to building fire safety design (GSA, 1972). Key features of *Appendix D* include:

- A concept of relative risk (the absence of risk is not feasible).
- Management goals as described in the context of acceptable levels of risk.
- Workable components of a fire safety system that can be adapted to any building.
- An event logic tree expressing relationships among the different system components.
- A method of calculation enabling the performance of alternative fire safety systems to be compared.
- The use of probability to describe fire safety performance.

Following the publication of *Appendix D*, activities relating to risk-informed systems approaches to building fire safety expanded considerably in the United States and internationally, including:

- Development of NFPA 550, *Guide to the Fire Safety Concepts Tree* (NFPA 550, 1995).
- Development of the Fire Safety Evaluation System (FSES) used in NFPA 101A, *Guide on Alternative Approaches to Life Safety* (NFPA 101A, 1995).
- Development of the *Building Firesafety Evaluation Method* (BFSEM) (Fitzgerald, 1985).
- Development of FRAMEworks (Bukowski et al., 1990; Hall, 1995).
- Development of CESARE-Risk (Beck, 1986; 1987; 1997)
- Development of FIRECAM (Beck and Yung, 1989; 1990)
- Development of CRISP (Fraser-Mitchell, 1994; 1997)

There are also a variety of other fire risk approaches in use or development internationally (Meacham, 2002), including in specific areas such as nuclear power (Siu, 2002) and chemical process safety (Barry, 2002). However, for the general built environment, most of the current approaches seem to be lacking from an applicability and useability perspective, either being too difficult and/or time consuming for use in practice, or lacking the sophistication required for the application, or lacking the data necessary to support the modeling and/or required decisions.

Recently, however, work undertaken by Notarianni (2000; 2002) charts a path forward for integrating risk information and uncertainty into fire engineering analysis and fire safety decision-making. In this work, Dr. Notarianni discusses the wide range of issues involved in decision-making under uncertainty, and provides an approach for cost-effectively incorporating risk and uncertainty into commonly used fire protection engineering tools. This is a significant step towards development of a tool for widespread use by the fire engineering community. Furthermore, her work in the area of decision analysis (Notarianni, 2000) nicely parallels the needs identified for risk-informed fire protection engineering design and regulation (Meacham, 2000). *Given the clear and pressing need for a risk, benefit and cost assessment and decision tool for regulation and design, as outlined above, considerable effort is required in this area*.

Data and Databases

To support all activities related to reducing the fire loss in the United States – be it in terms of life loss, economic impact, or other metric – data and easily accessible databases are needed. Furthermore, quantification of the uncertainty and variability associated with those data to be developed and catalogued in databases is required. There are numerous data needs for fire safety, ranging from material properties, to human factors, to risk data. Data needs other than for risk decisions have been discussed in many forums (e.g., SFPE, 2000; Cox, 2001), so the focus here will be on risk data issues.

The fire loss experience in the United States is generally considered well understood, as data are collected and published for such parameters as the number of fires by property class, leading sources of ignition, number of deaths and injuries, and dollar value of fire losses (e.g., NFPA, 1999). However, these data do not include all fire losses, and statistical methods are applied to infer the scope of the national fire problem. In some cases, loss data are only reported to insurance companies, and are confidential and not available to the public. In other cases, insurance companies do not get complete data either, such as when fires are extinguished when very small and only minor damage results, and when there are large deductibles or significant (or total) self insurance. In all cases, ignition frequency is severely lacking.

How one takes the available data, with its associated uncertainty, and applies it to a building fire risk problem, may differ significantly depending on one's confidence in the data and the methods applied to address the uncertainty (see, for example, Apostolakis, 1978; von Winterfeldt and Edwards, 1986; Morgan and Henrion, 1990; Notarianni, 2000). For example, consider the issue of collecting and using data aimed at understanding the fire risk situation in the United States. First, a metric to measure fire risk needs to be selected. This alone can be difficult. Consider the following ways one could measure a single metric: risk of fire death:

Deaths per million people in the overall population,
Deaths per million in a specific vulnerable or sensitive population,
Deaths per building use or occupancy type,

Deaths per hour spent in a facility,
Deaths within room of fire origin,
Deaths outside of room of fire origin,
Deaths by smoke inhalation,
Deaths due to carbon monoxide,
Deaths due to oxygen deprivation,
Deaths due to toxic substances,
Deaths due to elevated temperatures,
Deaths due to thermal radiation,
Deaths by month of year,
Deaths by day of the week, and
Deaths by time of day.

Depending on the risk metric selected, the risk of death can differ, and trends can be shown to be either increasing or decreasing. For example, in 1996, there were some 1,975,000 reported fires in the United States, resulting in some $9,406,000,000 in direct property losses, 25,550 civilian (non-fire fighter) injuries, and 4,990 civilian deaths (Karter, 1997). If one assumes a U.S. population of 250,000,000 in 1996, one could estimate the risk of death in a fire per overall population as $4990/250{,}000{,}000 = 1.996 \times 10^{-5}$. If one chooses to look at the risk of death in structure fires (4220 deaths, Karter, 1997), the risk estimate is 1.688×10^{-5}, a slightly lower figure. Looking only at non-residential structure fire deaths (140, Karter, 1997), the risk is only 5.6×10^{-7} – a significantly lower value.

In many regulated areas, a risk level of 1×10^{-6} is often targeted as being "reasonably practicable" (see, for example, Whipple, 1987; Meacham, 2000). If this were the case for fire, it would seem that the risk of death in non-residential structures is rather good. However, of the 140 non-residential fire deaths, 19 of them (13.6%) resulted from four fires in adult board and care facilities (Karter, 1997). If one were to assume a small fraction of the U.S. population occupy adult board and care facilities, say 0.5% or 1,250,000 people, the risk to life would be 1.52×10^{-5} – well above the overall non-residential structure fire risk and the 1×10^{-6} "reasonably practicable" target. Furthermore, considering that only four fires resulted in 19 deaths, one could argue that the fire risk in adult board and care facilities is unusually high (as compared with other non-residential facilities, which include hospitals, jails and other institutional occupancies, as well as offices, stores, factories and the like). Thus, when considering the overall population, the risk of death from fire in non-residential structures can appear quite low, and most would deem the risk level as being tolerable. When focus is placed on a specific subset, however (in this case adult care facilities), the risk of death from fire can appear to rise dramatically.

The above discussion on metrics becomes more complicated when injuries, economic losses, and other factors are considered. This clearly points to the need for a thorough risk characterization activity in order to understand and incorporate stakeholder input. In the end, the overall acceptability of a risk-informed performance-based code will depend on how consequences are defined, what metrics are used, what data are available, and the risk perceptions of the involved parties. Where data are lacking, judgments, and the process to elicit the judgments, are paramount to the overall acceptance of the risk characterization. In the end, whatever data are ultimately used should be well understood, including associated uncertainties, unknowns, inferences and judgments.

In addition to fire loss data and databases, comprehensive risk characterization will likely require specific information for assessment of incapacitation, death, content or structural damage or failure, environmental impact, or other losses or harms. Such information includes relevant concentrations, thresholds or tolerances, such as a maximum tolerable CO concentration, radiant heat flux or temperature. Many of these data are available in tables and text of the *SFPE Handbook of Fire Protection Engineering* (2002) and other sources. However, data are not available for numerous materials and systems, and the available data likely includes a mixture of test and/or scientific data, scientific and engineering judgment, inference and uncertainty, and the levels, types and sources of uncertainty are unknown or unreported.

One also must consider the variability in the population of concern. With respect to people, there are wide variations in age, physical ability and mental ability in the general population. This is important for risk analysis, especially when average or mean values are used to describe functions or activities, such as recognizing fire cues, making decisions and evacuating. For example, the elderly are typically more at risk from fire than the general population. This is due in part to age-related physical, mental and medicine-induced impairments, and is manifested in less overall ability to recognize fire cues, to make quick, lifesaving decisions, and to egress quickly to a place of safety. If an "average" time to hear an alarm bell is selected, an "average" decision-making time is assumed, and an "average" walking speed is postulated for an egress evaluation, what happens to those who cannot hear, make decisions or walk on their own? The more one knows about a population and how it is at risk, the better one's decisions can be regarding risk characterization, tolerability and acceptability.

Finally, the cost of fire and fire safety needs to be better defined, and associated data need to be collected and made available. Although performance-based design often promises lower costs, there has been little work undertaken to quantify the costs and verify the claim. For example, a design may claim cost savings by designing an automatic sprinkler system and reducing fire resistance. Although this may result in construction cost savings, the long-term maintenance costs may increase the total life cycle costs. Furthermore, if a significant change in use is desired for the building, the cost to upgrade the sprinkler system or add other fire safety features should be considered up front (this might be considered the cost to achieve flexibility).

From this brief discussion, it should be clear that data are needed for fire risk decisions, that work is needed to better define the types of data needed for fire safety design and regulations, and that uncertainty and variability needs to be reported with the data. As noted earlier, to assure that the "correct" data are collected and reported, data types and needs should be identified within a risk-informed regulatory framework that clearly links data to fire safety objectives.

Education and Training

Given that complex risk-informed decisions will be required in a performance-based regulatory system, a critical component of education and training for those at all levels of the regulatory, design and enforcement communities should be in the areas of risk and decision making. Such education and training should encompass risk concepts, risk characterization, uncertainty, variability, and decision-making processes and tools. *Whether part of university programs, continuing education or other, courses should be developed in the areas of risk and decision-making to support all levels of the building and fire communities*.

Barriers to Progress

As discussed above, significant barriers to progress include the lack of a common understanding of risk (and specifically fire risk), the lack of a complete framework for risk-informed performance-based regulation and design, the lack of significant databases of fire, risk and cost data, and the lack of a comprehensive fire risk and cost decision tool. If these needs are not addressed, there will be a significant challenge in implementing a performance-based building and fire regulatory system in the United States.

Conclusions

Each of the areas identified above are critical to the continued advancement of performance-based codes and fire safety design methods, and to the roles these mechanisms play in facilitating advancements in fire safety technology to reduce the fire burden in the United States. However, from a policy perspective, two areas stand out as being particularly critical for moving forward and gaining widespread and long term acceptance:

1. A framework must be developed that clearly links policy level objectives to data needs, design methods, decision tools, and building fire safety design solutions. This framework needs to clearly illustrate how the individual parts are interrelated and interdependent, and that development of test methods, standards, guides, analytic methods, and data – outside of such a framework – leaves the door open for confusion, rather than consensus, as the linkages required to demonstrate that the necessary connections have been made may not exist.

2. Decision support tools are needed, for designers, regulators and policy developers, so that all parties involved better understand the bases for fire safety requirements in the framework of levels of risk, cost and benefit acceptable to society.

The above items are closely related and desperately needed, as the current system forces too many decisions to be made without adequate justification of the bases for those decisions – by policy makers, regulatory developers, enforcement officials, and designers. In the near term, this will lead to wide variation in the application of performance concepts and criteria, and in the long term, could lead to significant differences in the level of acceptable performance, which if a significant loss occurs, could result in legal challenges to the performance system that could be difficult to defend.

From the perspective of data needed to inform technical, risk and policy decisions, two areas stand out as well:

1. Research is needed to adequately quantify magnitude and frequency of fire events for use in risk-informed performance-based decisions. Unlike a natural hazard event, fire does not impact a structure uniformly, and its impact is dependent on the structure, its protection features and its contents. Key questions that need to be addressed include: how should fire loads be defined, how should probability of occurrence be characterized, and how can the fire loads be regulated?

2. Research is needed to develop an analytic tool to describe and predict the totality of how buildings and occupants perform when subjected to design fire loads.

The National Science Foundation can play a key role in helping to reduce the fire burden in the United States by supporting research in each of the above areas – through individual research grants, and through the establishment of a multi-disciplinary center for fire performance research. Of these, support for a multi-disciplinary center would be the most important, as it would serve to link a broad cross-section of technical and policy researchers, private sector firms, and regulatory agencies to collectively identify and tackle the most important research needs. Without such cross pollination, there will remain the risk of individual research being conducted that, while in itself important to the advancement of science, does not contribute to advancements that can benefit the nation as a whole.

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Transferring Fire Safety Technology Research from Academia to Practice: A Public Policy Issue at the Local Level

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Abstract

Transferring fire safety research from academia to practice by governments at the local level is dependent upon getting issues through the public policy process. Making public policy is a political process, where public value is a critical factor. Among the many public policy making models, the rational-comprehensive model is considered the "ideal." Yet most scholars acknowledge, more practical models suggest that public policy is made incrementally. Two significant barriers exist in moving fire safety technology to the public policy agenda in local governments. First, many fire service administrators and other bureaucrats were trained and educated to stay out of politics. Secondly, many bureaucrats (fire chiefs, fire marshals, and building officials) within the system are heavily invested in the current system and often feel threatened by new technology that they do not always fully understand. Colleges, universities, and professional organizations could more effectively collaborate to offer practical courses and seminars to decision makers, in the art of transferring fire safety technology through public policy.

Introduction

The purpose of this paper is to frame the problem of transferring fire safety technology research from academia to practice within the context of the public policy making process, particularly at the local level. The fire service, fire departments in particular, play an important role in the adoption of new technologies yet there are barriers related to the political process and the adoption of new public policies. It is well known within the fire service that the adoption of codes and standards is a local issue that requires a great deal of effort and understanding among local officials and politicians. The adoption of new fire safety technology based on sound research is important to advance fire life safety and building safety in the built environment of our communities. Therefore it is important for fire service administrators, other public administrators, elected officials, researchers, scientists, and teachers to more fully understand the policy-making process at the local level.

Public Value

Bringing politics and science together to bear on the problem at hand can benefit from a discussion about public value. Public " . . .value is rooted in the desires and perceptions of individuals . . ." (Moore 1995 52). Moore continues that public value can be provided in goods or services and that one of the services is to adopt regulations that govern how things are done in the community in the name of the public good. Transferring fire safety research and knowledge into the built environment of a

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community is generally considered a public good, i.e., a good that is non excludable and non divisible. However, it would be remiss not to acknowledge that there is a considerable fire safety technology research agenda focused on materials and processes that are excludable and divisible in the private sector. These are the products and process that can be adopted by some manufacturers, but not all, or used by some building architects and engineers but not all.

Evaluating public value is a constant in any public policy debate, whether consciously or unconsciously engaged in by the actors. This debate is a mixture of the technical merits of the policy and the political merits of the policy. Some of the questions asked are as follows. Who will pay for this policy? What will this policy accomplish? How will the policy be implemented? How will the success of the policy be measured? Obviously the answers to these questions will vary from individual to individual as well as from institution to institution. It is well to understand that it is a primary role of the actors who are proposing the policy to understand these nuances and to recognize the most appropriate mix of technology and politics to get the policy adopted.

Public Policy at the Local Level

What is Public Policy?

There are a variety of definitions for public policy, however Thomas Dye (1998) provides a good working definition that is applicable to this paper. Dye defines public policy as simply what government does or does not do. Thus, public policy includes all of the policies adopted by the elected body of a local government and also includes the regulations and policies that are set by the bureaucracies within the local government, e.g., the local fire department or building department.

Who are the Actors in the Public Policy Process?

The public policy making process includes a vast number of actors, some of whom are considered official actors and some of whom are considered unofficial actors (Birkland 2001). It is the collective efforts of these actors that culminates in the adoption, or change in public policy. The official actors include the fire chief, fire marshal, building official, city manager, city engineer, and other public administrators whose roles and functions are to regulate, administer, and otherwise adopt, implement and/or make public policy. Some of the unofficial actors in the process include the members of special interest groups, e.g., the homebuilder associations, contractors, architects, builders, consultants, fire protection engineers, and scientists. Other unofficial actors include the media, citizen groups, business owners and managers, and individual concerned citizens. These actors come together in a variety of ways to make and influence public policy at the local level.

Models for Making Public Policy

Scholars have developed various public policy-making models over the years in an attempt to explicate the process and to teach students and practitioners how to make public policy. The following models represent those that are more frequently discussed and that might better illuminate the world of making public policy. A brief review of these models will help frame the discussion about how the fire service community might approach transferring new fire safety technology research into the community by changing public policy.

The Generic Model

Most public administration scholars and political scientists agree that there are some basic steps, or stages, that can be ascribed to the public policy process (Anderson 1994; Dunn 1994; Theodoulou 1995; Dye 1998; Birkland 2001). These stages generally include the following. First, a problem or issue emerges in the system and gets the attention of policy makers. Second, the issue is placed on the public agenda. This gives the agenda item legitimacy and a place in the rankings of public issues to be decided. Third, the issue is developed in the form of a proposal for consideration by the political decision-making body. Fourth, support is sought to get the proposal adopted as the government's policy. Fifth, the policy is implemented. This is normally a function of the bureaucracy. In the case of transferring fire safety technology research, and knowledge, implementation typically involves the participation of the fire service (fire department) and the building department, as well as official and unofficial actors who are involved in the development and maintenance of the community's built environment. Lastly, the consequences of actions taken to implement the policy are evaluated. It is important to examine, not only the obvious consequences, but to make a special effort to discover any unintended consequences. Unintended consequences can be either negative or positive, but in either case, should be examined before determining whether the policy was successful or not.

The Rational-Comprehensive Model

The rational-comprehensive model is generally viewed as the ideal model because it relies on rational thinking, scientific analysis, and sound logic (Weimer & Vining 1999; Birkland 2001). The underlying assumptions for this model are that the actors in the process are rational decision-makers who follow a logical path in developing public policy. The rational-comprehensive model assumes that the rational actor will be presented with a problem and a goal, gather as much information as possible about the costs and benefits, completely analyze all of the information, and select the solution that will maximize the benefits, minimize the costs, and achieve the stated goals. The rational-comprehensive model is very appealing to rational actors, especially scientists, engineers, economists, and most firefighter types because of its rationality and logic; to firefighters this is often referred to as just "common sense." However, the rational-comprehensive approach is seldom achievable because of the political and human factors that must be considered (Lindblom and Woodhouse1993; Kingdon 1995; Birkland 2001). Hence, other models have been postulated to try and capture these nuances.

The Incremental Model

Lindbloom (1959) presented an alternative to the rational-comprehensive model in his article titled *The Science of Muddling Through*. Lindbloom presents the notion that public policy is not a logical and rational process but instead an incremental process that is a function of timing and opportunity. He posits that policy-making actors are not always rational and certainly not able to develop a comprehensive approach because of so many political barriers. Therefore, public policy is a result of making small, incremental changes to existing policies, which emerge over time into a policy that often appears to be a comprehensive public policy.

The Garbage Can Model

The *Garbage Can* Model (Cohen, March and Olsen 1972) is another alternative to the rational-comprehensive model. In this model a variety of policy alternatives, issues, and solutions are tossed into the metaphorical "garbage can" where they are mixed with each other. The *garbage can* metaphorically is filled with problems, solutions, and actors all looking to find each other. Problems are looking for solutions and vise versa while actors are seeking ways to get problems and solutions together.

Bounded Rationality

The rational-comprehensive model requires all of the possible information available and the capacity to process the information in a rational and logical way. Since this is an enormous task, which typically overwhelms the capability of humans and human systems, Simon (1976) offered a concept he coined "bounded rationality." That is, Simon recognized that the capacity to process large amounts of complex and complicated information is bounded by the limitations of humans and their machines. Thus it is not reasonable to expect that all information will be available and brought to bear on any given issue nor will the system have the capacity to process such large amounts of information when making public policy.

The Streams Metaphor for Making Public Policy

John Kingdon has offered yet another approach. Kingdon (1995) offers his "streams" metaphor, which includes, a problem stream, a policy stream, and a political stream that are brought together to make public policy. He also presents the notion of "policy entrepreneurs" and "policy windows" in describing how these streams converge on an issue. Policy entrepreneurs are actors who may be official actors or unofficial actors, as noted above, and who have a solution and are looking for a problem, in which to apply it. When the opportunity arises, i.e., a policy window opens; the policy entrepreneur is ready to offer the solution to the problem. Fire protection engineers, fire chiefs, fire marshals, and building officials represent some of the official and unofficial actors that could be policy entrepreneurs.

Barriers at the Local Level

Political Barriers

Many fire chiefs, their bosses (city managers), and others within the bureaucracies of our local and state governments are reluctant to get involved in anything they determine to be politics. Yet, it is the political process that is used to set public policy and it is public policy that dictates what government does and what governmental agencies do. This process, then, has a great deal to do with the fire service communities' ability to get local governments to adopt new technologies and fire safety methods. There is a rational explanation for this dilemma. In the public administration literature it is referred to as the politics/administration dichotomy, which means that public administration scholars have debated, for over a century now, the role of public administrators.

In 1887 Woodrow Wilson published an article that was used as the foundation for the creation of a professional discipline for public administration. Wilson argued that public administrators should be professional and separate from politics, where their job is defined as carrying out the public policies that are set by elected officials in the political process. However, more recent public administration literature acknowledges that public administrators cannot, and should not, be completely separate from politics since they are a part of the larger system and have a legitimate role to play (Birkland 2001, Shafritz and Russell 2001). This includes the setting of public policy, which is a political function in our system. It is important to understand this as background in the discussion of transferring fire safety technology research and education to our communities, since the fire service community needs to use the political process to get adopted public policies that are important to transferring fire safety technology research to our communities.

The above background might explicate why many of today's public administrators, especially the more senior fire chiefs and other public administrators who were trained and educated in a system that stressed a separation between politics and administration, are reluctant to get involved in changing public policy. Although many of the younger fire chiefs are very aware that they have a political role to play, there are still a great number who believe that politics is a dirty word and it is something that they should avoid.

Investment Barriers

Many fire departments, and individual actors, have an enormous investment in their current system: an investment that they measure in terms of time, money, understanding, and application. Most departments have individuals who have invested their entire career (or a great portion of it) in the development and adoption of the codes and standards they currently use. Often they have spent many hours of personal time on committees developing these codes and standards plus an even greater amount of time learning and teaching others how to interpret and apply these codes and standards. For many of these actors, performance-based codes, fire protection engineering solutions, and the application of state-of-the-art research, and fire safety technology represent a major shift (often perceived as a major threat) in the way the have been educated and trained to do things. Some are embracing these new breakthroughs while others are standing on the sidelines viewing these new notions with much trepidation.

Adopting the latest technology presents fire departments and its members with many challenges. These challenges range from getting the dollars to train the existing workforce to use these new tools, to hiring fire protection engineers and other professionals, to dealing with the realities of managing a somewhat major shift in the existing culture. These barriers and resistors to change are not revelations but do represent significant challenges to all actors in the system. When these change resistors are added to the mixture with a reluctance to engage the political public policy making process, the challenges can be formidable.

Possible Solutions

Making public policy at the local level is not complicated but it is complex. The environment is ever changing and the actors are different from locale to locale, which is one of the oft-heard complaints by architects and engineers who do business throughout the U.S. Many of these professionals have argued for a more universal (or national) adoption of codes and standards, but that is not likely in the near future given the political system of the U.S., which places a tremendous, and historical, emphasis on the notion of local control. Understanding the public policy making process at the local level is the first step in finding viable solutions to effectively transfer fire safety technology research to the world of practice at the local level.

Rationalism Versus Incrementalism and Decision-Making

Rationalism versus Incrementalism is essentially a debate over how decisions are, or should, be made. The rational-comprehensive model is very appealing because one of its axioms is that problems are rationally and logically identified. Then a well-ordered approach to finding the best solution is based on all of the information available, followed by sound scientific analysis of all alternatives before a solution is selected. The rational approach makes a lot of sense to actors who are trying to solve a perceived technical problem, i.e., a technical problem deserves a technical solution.

Incrementalism, as described above, can take many forms (and usually does) allowing for small changes in public policy. Although, the incremental approaches do not typically provide for comprehensive solutions, they do provide for partial solutions that are politically acceptable. This is often hard for rational thinking fire chiefs, fire marshals, fire protection engineers, and researchers to accept but it recognizes the realities of the system. The incremental approach recognizes the political system and the need to find a political solution.

Technical Problems Versus Political Problems

Rational actors are often frustrated with the system when the technical solution they propose to solve the technical problem is not accepted by the system. They often go back to their department with the idea that they just need to do a better job of presenting the evidence to support their proposed solution. All they need to do is provide more data, and make their arguments more clear. After revising their report, they resubmit it only to find that it is still not acceptable. Even more frustrated they go back to their department and work even harder on providing even more data, better graphs, and strengthening all of their arguments. They resubmit their report and are again rebuked. This cycle can go on forever and when it does, the rational thinker in the system, often the fire chief or fire marshal, are broken (they can become organizational casualties) and complain that the system won't accept their proposal because it is too political.

In fact they are right about the system being political (too political may be an overstatement) but they refused (or were not able) to acknowledge that it was the political part of the system that they needed to address. In other words, they had a political problem and were trying to solve it with a technical solution. This occurs very often at the local level. All public policy issues at the local level have a political side that cannot be resolved by technical solutions, no matter how well documented and rational the technical report. This emphasizes the need to first recognize whether the problem is a political problem or a technical problem. Then, once the problem is appropriately categorized the appropriate solution can be found. This is not to minimize in any way the importance of good technology to solve technical issues. In fact, without good fire safety technology research to support the technical solutions proposed, the political solutions will most likely fail. There is a fine balance in applying the art (political) of getting an issue adopted as new or changed public policy and the science (technology) to support the policy.

Education

Another obvious solution is expanded and improved education. Often the effort is directed to train fire marshals, technicians, code enforcers, and engineers in the use of sophisticated technical tools required to use these new technologies, without any education about the political environment in which these technologies are applied. Educating decision makers, fire chiefs, fire marshals, and building officials, in the art of making public policy is less often available. This education should include some of the topics presented here and should also emphasize the need for each fire service actor in the process to understand their role and how they can contribute to the adoption of the best fire safety technology for their community. Colleges and universities can play an even greater role than they presently play by building public policy courses into their fire service curriculums. Public administration programs typically have at least one public policy course in their curriculum; however transferring fire safety technology usually is not a topic of discussion since most of the policy professors do not have any background in fire service issues. Another role for educational institutions is to partner with professional organizations like the Society of Fire Protection Engineers, the International

Fire Marshals Association, the International Association of Fire Chiefs, the International Association of Firefighters, and the International Code Council (to name just a few) to offer professional development seminars that are specifically focused on setting the public policy agenda for the transfer of fire safety technology.

Conclusion

Transferring fire safety technology research from academia to practice requires getting it adopted as part of the community's public policies. Public policy includes the regulations and policies of governmental agencies like fire departments and building departments. Getting fire and building departments to change their regulations to accommodate state-of-the-art fire safety technology is often considered a problem within the bureaucracy and not a political problem. However, as presented in this paper, setting the public policy agenda is a political process and fire service actors who recognize this will increase the probability of getting their policies adopted. Kingdon's (1995) streams metaphor explains much of what is happening in the fire service with regard to the adoption of fire safety technology. Many fire protection engineers, fire marshals, plans reviewers, building officials, educators, and consultants can easily be categorized as "policy entrepreneurs," that is they have a solution that they believe will solve (or at the very least mitigate) the fire safety problem in the United States. This can be a good thing if a concerted effort is made to educate the fire services in the public policy process.

Some specific actions may be in order. First, recognize that adopting fire safety technology research is a political problem, not just a technical problem, but that the adoption of good public policy relies on sound research. Second, it is important to identify the official and unofficial actors in the process. Moore (1995) reminds us that public managers (fire officials) have a responsibility to recognize and try to improve the value of the services they provide to the public. He also informs us that individuals define and perceive public values differently. Therefore, it is important to understand these perceptions as they relate to fire safety technology. Third, it is important for all fire service actors, especially decision makers, to understand the nuances of making public policy. This includes an understanding of the rational-comprehensive model and the various incremental models that are offered as alternatives. Lastly, it is critical that the problem is appropriately identified. This is especially true when an initial attempt to get fire safety technology on the public policy agenda is not successful. It is very hard (usually impossible) to solve a political problem with a technical solution, yet it is important to recognize that the political solution most generally will require sound science as a foundation. This may seem paradoxical to some rational actors. However, I believe it is clear that understanding the politics of setting public policy is important before we can successfully set a sound fire safety agenda at the local level, which effectively transfers fire safety technology research from academia to practice.

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PUBLIC POLICY ISSUES: BRINGING FIRE RESEARCH INTO PRACTICE

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ABSTRACT

Several observations from two perspectives are used to help identify issues with implementing fire research results. These issues range from finding a way to do needed research to working with stakeholders. Practitioners need assistance now, and researchers need to bring results into practice. The management model concept of use-inspired fundamental research is more effective than the traditional "hand-off" approach. Different choices among safety criteria for desired outcomes may also be useful. A viable stakeholder organization is seen as key.

Introduction

When we look at the current state of fire research and compare it to where we started about 30 years ago, it is not difficult to say that great strides have been made, reflecting enormous achievement and tremendous progress. Huge advances have been made in knowledge, computer models, data and education. We clearly see the use of this knowledge and these data and models in the performance-based design encouraged by emerging performance-based codes and standards worldwide, coupled with a growing professional practitioner workforce composed of fire safety and fire protection engineers. Yet we still hear pleas from fire researchers that an adequate degree of fire safety has not been achieved and more research is needed. So where's the problem? From my perspective, there is little doubt that a significant part of the problem has to do with implementation, getting research results into practice.

Perspectives

I'd like to summarize some observations on the current state of affairs to help focus on needs and issues as they pertain to technology transfer, or moving research into practice. First, it will help you to appreciate my perspectives in forming the basis for my observations. FM Global is an insurer of large commercial and industrial customers worldwide, providing coverage in property protection and business interruption. Many of the Fortune 500 companies are our customers. We do not provide insurance on an actuarial basis; rather we promote loss prevention through scientifically investigated and engineered measures. Typically, our customers like and want this approach. As Vice President of Research for FM Global, it is my responsibility to assure a sound technical basis for understanding hazards and for assessing and mitigating risks… practically, cost effectively, in the field. Efforts must be balanced between trying to ascertain tomorrow's hazards and responding to today's losses.

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The International FORUM for Cooperation in Fire Research is a consortium of the heads of large fire research organizations worldwide. Members are dedicated to working together to address large, critical fire research issues. We routinely discuss the technical, organizational and management issues we face, seeking commonality as a basis for cooperation. As Chair of the FORUM, I try to find common issues to pursue and reach agreement among the members. As most of you know, many of these organizations are being privatized from independent government sponsored laboratories to commercial ones. These changes foster competition rather than cooperation. Needless to say, it is increasingly difficult to find commonality for cooperation. Yet there are still items on which we have strong agreement: the continuing need for more scientifically-based fire research, the recognition of areas needing research (though priorities differ), the benefit (and difficulty) of collaboration and the generation of position papers as a vehicle to communicate internationally.

Observations

With the above perspectives for background, I present the following observations.

1. What is fire research? I have often heard each of the following items described as or alluded to as fire research. While there may be times when each of the first three bullet items may be involved in research, <u>it is the fourth bullet that generates new sound knowledge</u> and is recognized as what advances the field.

    - standardized testing – routine testing conducted according to strict protocol
    - scenario testing – testing done, often at full-scale, to simulate real fire situations
    - model application
    - scientifically-based model development, experimentation, analysis
        - ✓ first principles
        - ✓ dimensionless parameters
        - ✓ generalized solutions

2. <u>Key current drivers of fire research are performance-based design and global product testing for acceptance</u>; to a lesser degree, loss prevention, incident investigation and improved phenomenology also provide motivation for research efforts.
3. The practice of <u>fire safety engineering/fire protection engineering may be outpacing knowledge</u>. The accuracy and precision of models being used in practice may not be adequate in all applications; however, uniformity and consistency of application is a key factor.
4. <u>Global trade is a strong factor</u>. The drive for global acceptance of products for emerging markets influences many decisions on what is done and how money is spent.
5. As a result of item 4. above, there is <u>movement from scientific research to ad hoc testing</u>, which not only does nothing to advance the field, but also strengthens the barrier to research needed for next generation testing.

6. Because of the commercialization of laboratories the work being done is less independent and caters more to special interest, which usually means the work is done less for understanding and more for problem-solving, and becomes less scientific and more empirical.
7. Lastly and perhaps most importantly, researchers must bring results into practice. The key word here is “bring”. In today’s environment, it is no longer acceptable or effective simply to hand off research work to practitioners. For research to be useful, it must be implemented effectively, and to be implemented effectively, researchers must work with other stakeholders from origin to (and sometimes through) implementation.

Interestingly, these observations are shared among researchers at FM Global and the FORUM.

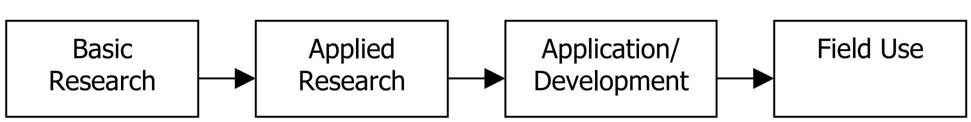
Research Needs

From a technical consideration, I believe there are two high level fire research needs; however, the achievement of both can be greatly aided through public policy positions, and both have breakthrough potential.

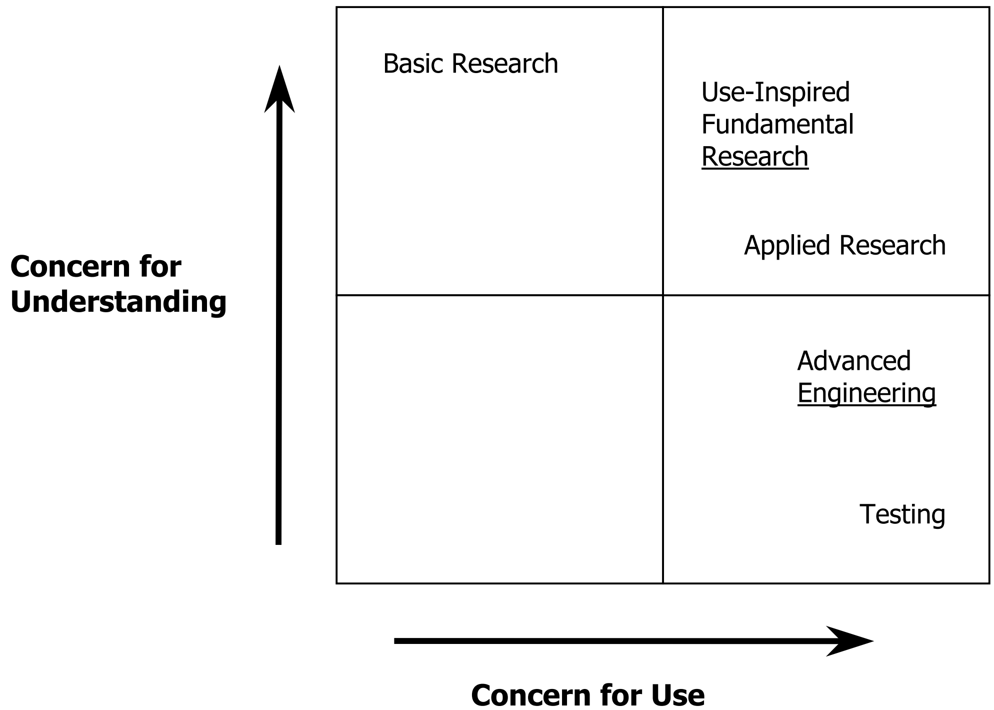
1. The ultimate goal for fire research is accurate first principle, end-use models with reliable material property data. The achievement of this goal contributes significantly to both improved performance-based design and next generation standardized tests. What is needed specifically are better ways to measure accurate material property data for use in first principle models, which also need to be developed further. (A FORUM position paper was generated on this subject.)
2. The second need is to do more focused scientifically-based research that is also more amenable to technology transfer. Two suggestions are put forth. In the current environment, researchers have to do a better job of “selling” the value of their work to other stakeholders, and get their buy-in. The management model concept of use-inspired fundamental research has proven useful to me and can be useful in a larger arena. Also, we should consider more broadly the criteria commonly selected for evaluating fire safety outcomes. These suggestions are discussed further below.

Use-Inspired Fundamental Research

Our organization recently underwent a significant merger, and there is no doubt that FM Global Research is expected to perform and be measured on useful deliverables to our business. I would like to share with you an approach I’m using to help convince our top management that funding fundamental research is both justified and beneficial to our business needs. The approach focuses on **use-inspired fundamental research**. The traditional approach for using research results has long been depicted as follows:



Instead of using this "hand-off" model, wherein basic research may not have much concern for ultimate use, I propose the following model be used:



In this chart, the ordinate shows an increasing concern for understanding, while the abscissa shows an increasing concern for use. This model clearly indicates the difference between traditional basic research and use-inspired fundamental research.

For clarity, I offer the following definitions:

- Use-Inspired Fundamental Research
  - Investigation into mechanisms or first principles with end use in mind
- Applied Research
  - New investigations into specific applications
- Advanced Engineering
  - Transferring existing knowledge to new applications
- Testing
  - Scenario – testing conducted with a simulated real configuration
  - Standardized – testing conducted according to a recognized protocol

I find this model useful because it not only shows that fundamental research can be conducted with end use in mind, but it further depicts how testing may get you an answer to a specific question but not give you an understanding of the issue. To conduct fundamental fire research in today's environment, it is essential to operate on the right side of this chart, with most work occurring in the upper right quadrant, for understanding, and validation work done in the lower right quadrant.

Possible Fire Safety Design Outcomes

When performance-based codes, standards and design are discussed, usually there is little mention of what desired outcome is being referenced or used. Most often, the focus is on people safety, sometimes inferring public safety, but still there is ambiguity if the specific outcome is not clearly stated. Oftentimes, even when the desired outcome for people safety is clearly stated, there can be a variety of solutions, with different solutions determined by different practitioners. This may not be so bad unless significant resources are being dedicated to these new solutions, in which case one must ask if there is a better way.

In fact, there are many cases when the desired outcome may not be related to public safety, per se. Listed below are a number of possible outcomes, most of which have been used in some form of performance-based design. This list is not intended to be comprehensive, but rather to illustrate that a coordinated approach among key stakeholders may produce overall better results.

Possible Fire Safety Outcomes

- safety for room-of-origin occupants
- safety for building occupants
- safety for general public
- protection for building of origin
- protection for neighboring structures
- protection for historical buildings
- protection for firefighters
- protection for infrastructure
- operability

As we have seen with recent natural catastrophes and the World Trade Center incident, protecting people and recovering from a disaster usually depend on more than a scheme that looks at people only. A viable economy and infrastructure (food, water, shelter, medical care, electricity, supplies, transportation, jobs, etc.) can be equally significant for short and long term recovery as survival itself. If the above list is rearranged as shown below, perhaps many desired outcomes can be achieved by focussing on a certain few. In this way, using what is already known and modifying it slightly for broader application can focus the application of resources and provide greater benefit to society.

Grouped Fire Safety Design Outcomes

- protection for building of origin
  - ✓ safety for room-of-origin occupants
  - ✓ safety for building occupants
  - ✓ safety for general public
  - ✓ protection for neighboring structures
  - ✓ protection for historical buildings
  - ✓ protection for firefighters
- protection of infrastructure
  - ✓ communications, utilities, transportation systems, building stock
  - ✓ operability

By focussing on two outcomes for which much work has already been done, many other outcomes can be achieved with relatively modest additional investments. Again, a dialogue among key stakeholders could produce the focus and understanding needed to achieve this kind of benefit.

Implementation Issues

Four issues relating to implementation can be highlighted.

1. Getting scientific research done toward ultimate goal – A number of factors can be barriers to getting the right work done. Decisions sometimes are strongly influenced by politics or economics, rather than science. Researchers, practitioners and other stakeholders often have different views, different approaches, different criteria, different priorities, and often compete. Lastly, the reality is that funding for fire research is too limited to pursue everything.
2. Accuracy, precision, uniformity (what's done) and consistency (how it's done) – On the one hand, performance-based design is immature, experience is limited and results can vary. On the other, how good is good enough? Questions of accuracy, precision, uniformity and consistency need to be addressed in a representative arena. It is noteworthy that key international standards organizations have technical committees working on these issues.
3. "Solutions" can create problems when all key stakeholders are not involved. We already have encountered a number of facilities whose performance-based design resulted in an uninsurable facility. Lessons can be learned from these pioneering designs, but we also expect more such examples as global markets grow.
4. Global impact and national direction – Although this workshop has a national agenda, all of these issues need to consider global concerns.

Conclusions: Fire Research Implementation Issues Needing Public Policy Support

1. Obtain agreement, buy-in on key fire research direction, needs, approaches, goals from stakeholders outside the research community. (FORUM is planning to use position papers to help gain support across boundaries.)

2. Recognize and address global concerns and influences.
3. Consider more broadly the efficacy of safety criteria for various outcomes.
4. Establish an effective stakeholder organization. This is the single most important item since success here can greatly assist with the first three. A champion is needed (preferably not a researcher), and the group should include societal decision-makers, the fire services and key industry, trade and professional groups. (FORUM is already striving for this, and is willing to work with others.)

U.S. Explosion Research and Education Needs

Robert Zalosh[1]

ABSTRACT

U.S. explosion research capabilities have been in decline since the U.S Bureau of Mines explosion research program dwindled and then disappeared. There are some isolated productive explosion research facilities and programs, but the coordinated university-government-industry programs sponsored by the European Union and by some Asian countries dwarf their size and number. It is impossible to know whether this decline in U.S. explosion research capability is affecting U.S. explosion losses and casualties because there is no broad-based national explosion incident database. It is important to develop such a database and to initiate coordinated university-government-industry explosion research projects on specific issues in gas explosions, dust explosions, and blast waves.

Introduction

The customary introduction to this type of overview paper is to provide some context; in this case, some context on how explosion hazards and challenges fit into the overall U.S. fire safety picture. Although, the lack of a reliable explosion incident database renders it impossible to provide accurate context, a rough measure can be ascertained from NFPA published accounts of reported large-loss fires (Badger 2001), and of the deadliest fire and explosion incidents (Hall 1988).

Six of the 26 losses causing at least $10 million property damage in the year 2000, as summarized by Badger, started as gas explosions. Five of the six occurred in industrial/manufacturing/storage facilities, and the sixth was ignited in a large, single-family residence. Casualties and damage in one incident were exacerbated when the gas explosion triggered a secondary dust explosion.

Hall's accounting of the deadliest U.S. fires and explosions in the period 1900 to 1987 had 59 mining incidents out of a total of 98 incidents. Most of the mining incidents were methane and/or coal dust explosions. At least eight of the other 39 incidents started as explosions, and an unspecified number started as fires that later produced explosions. Several other incidents were not listed as explosions, but actually originated as either a boiler explosion or an ammonium nitrate explosion.

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The large number of deadly coal mine explosions in the first half of the twentieth century prompted the Bureau of Mines to undertake a productive explosion research program. A large portion of our current understanding of gas explosions and dust explosions, as well as several practical explosion protection measures, stem directly from the Bureau of Mines research projects from the 1940s through the 1980s. However, the Bureau of Mines was dismantled in the 1990s, and now the U.S. needs to look elsewhere for new explosion protection technology.

Explosion Research Infrastructure

Current explosion research activity in the U.S. is highly fragmented. Figure 1 illustrates this fragmented approach in the form of a conceptual plot of explosion test scale versus number of test facilities. The test scale is important because reliable scaling laws do not exist for several key explosion phenomena such as flame accelerations. The number of facilities is also important because of the need for multiple tests with different configurations, fuels, instrumentation, etc.

As indicated in Figure 1, there are a few large-scale government explosion test facilities, such as those at Sandia National Laboratories and the Department of Energy Nevada Test Site. There are more smaller-scale industrial explosion research facilities, such as those at FM Global, Southwest Research Institute, and Fenwal Safety Systems. Finally, there are several good laboratory-scale explosion test facilities at universities such as Princeton and the California Institute of Technology. These three groupings are shown as separate areas in the plot because there is very little coordination among them.

European explosion test facilities are not only more numerous in all sizes, they are also used for integrated explosion programs with coordinated participation of government, industry, and university research laboratories. Some examples of these programs are:

- Testing Methods for Electrical Apparatus Installed in a Dusty Environment with a Potential Risk of Explosion (Participants: UK Health and Safety Executive, Polytechnic University of Madrid, and Deutsche Montan Technologie, 2001)
- Determination of Safety Categories of Electrical Devices in Potentially Explosive Atmospheres (SAFEC 2000)
- Explosive Atmosphere: Risk Assessment of Unit Operations and Equipment (RASE 2000)

In each of these programs, a project coordinator issued one synthesis report, and individual research reports and/or technical papers were issued by the participating research organizations. Furthermore, research results are being used to assist in the development of European standards for explosion protection. In some cases, international standards bodies such as the IEC are adopting these European standards.

The coordinated approach among universities, government laboratories, and industrial research facilities is also being used in European and Asian explosion research programs of a more theoretical nature. The need for such coordination in Computational Fluid Dynamic (CFD) simulations of explosions is illustrated in Figure 2. In order to conduct CFD explosion simulations involving complex chemistry and fluid dynamics (for example, for dust explosions and for multi-compartment gas explosions), the required human and machine computational resources are beyond the capabilities of virtually any single research facility. However, a coordinated theoretical approach is allowing CFD and other techniques to be applied to separate phenomena and configurations, with results leading to an improved understanding and capability to benefit the entire explosion protection community. One example is the two-dimensional CFD simulations of dust explosions reported by Zhong and Deng (2000) as their university's contribution to a coordinated research program on Explosion Reaction Engineering funded by the National Science Foundation of China.

The thriving explosion research programs in Europe and Asia and the contrasting isolated and fewer explosion research projects being conducted in the U.S. have caused the center of explosion protection technology to be transported overseas. It is creating a tremendous burden on the NFPA Explosion Protection Committee to digest the overseas research results and to adapt them along with the isolated U.S. explosion research programs (such as FM program described by Tamanini and Valiulis, 1996) to develop explosion protection guidelines suitable to U.S. facilities. The tortuous development of the most recent edition of the Guide for Deflagration Venting (NFPA 68-2002) is an example of these difficulties.

Specific Explosion Research Needs

Although there are many important specific explosion research needs, all but two apply to particular types of explosion phenomena, such as gas deflagrations, gas detonations, dust explosions, and blast waves. The two research needs that transcend individual types of explosions and explosion phenomena are 1) development of an explosion incident database that can be used to provide data comparable to the data available in the NFPA and NFIRS fire databases, and 2) establishment of a coordinated university-industry-government explosion research program to tackle the most outstanding need identified by a panel of U.S. explosion experts.

With regard to needed research on specific explosion phenomena, this author recommends the following:

- Development of a predictive capability for flame speeds and flame accelerations in non-uniform gas-air mixtures of the type that arise in buoyant gas releases, vaporization of flammable liquid spills, breaching of pressurized gas piping in a large room or building, and backdraft explosions.
- Development of a predictive capability to determine the risk/probability of deflagration-to-detonation transition for gas deflagrations in highly turbulent environments and in highly obstructed environments of the type often encountered in industrial process facilities handling flammable gases and vapors.

- Provide a realistic method to estimate the size and concentration of the dust cloud that will be formed from accumulated dust layers during a secondary dust explosion, as illustrated in Figure 3 (from Eckhoff 1997).
- Develop a predictive capability for blast waves propagating within buildings; both for blast waves produced by detonating explosives and for blast waves produced by the venting of deflagrations.
- Acquire a sufficient understanding of blast wave generated glass shards and other secondary fragments so that blast-resistant windows can be developed and the risk of secondary fragment blast injuries can be assessed.

These last two explosion research topics are particularly pertinent to the nation's terrorism threat preparedness. The first three topics are important explosion protection issues for worker safety and firefighter safety, as well as general industrial loss prevention.

Explosion Protection Education and Training

Formal academic courses in explosion protection are extremely scarce in U.S. universities and colleges. To this author's knowledge, only one of the fire protection engineering curricula offers such a course. The American Institute of Chemical Engineers (AIChE) program entitled Safety and Chemical Engineering Education (SACHE) provides educational packages on explosion protection pertinent to chemical processing facilities, and some unknown number of the 125 SACHE member colleges use these packages in their undergraduate chemical engineering courses. These packages allow professors without special expertise in explosions to incorporate the subject into a general process safety course without having to first undergo tedious self-education without benefit of a mentor or textbook.

Most safety professionals, fire protection practitioners, and loss prevention engineers acquire some knowledge of explosions through on-the-job training or self-education. Several highly protected risk insurers and some of the large oil and chemical companies are examples of corporations with formal on-the-job training. In addition, there are some continuing education explosion courses provided under the auspices of organizations such as AIChE. However, many engineers and safety personnel face their first major explosion hazard or explosion incident investigation without benefit of the fundamental knowledge needed to go beyond the regulations and consensus or corporate standards.

European universities provide a much more extensive array of formal education courses in fundamental explosion concepts and formal mentoring in explosion protection technology. Some of these universities include the University of Central Lancashire, the Univeriste' de Poitier, and the University of Bergen. The result of the more focused explosion education in Europe is inevitably to increase European capabilities in explosion protection vis-à-vis those in the U.S. Asian universities probably also provide more opportunities in explosion protection education than does the U.S. despite the abundance of excellent U.S. faculty and courses in the more general subject of combustion. It would be useful to address and reverse this widening gap between U.S. and Asian and European educational opportunities in explosion technology.

Overcoming Explosion Protection Barriers

The primary barrier to improvements in U.S. explosion protection research, explosion education, and overall explosion protection technology is the absence of either a federal government agency or a large industrial consortium that recognizes explosion protection as an important part of its mission. Although some federal agencies address explosion issues within a narrow purview, there is currently no agency that is willing to undertake the type of comprehensive explosion research that the U.S. Bureau of Mines conducted while it was active. The limited explosion research projects sponsored by the U.S. Department of Agriculture to address grain dust explosions are indeed productive, but they have not lead to advances in other explosion hazards or applications. The result is that we now have an accurate count of the average annual number (12) of grain dust explosions in U.S. grain handling facilities, but we have no idea of how many dust explosions there are in all the other U.S facilities handling combustible powders and dusts.

Likewise, despite the proprietary loss data collected by individual U.S. property and casualty insurers, we don't really know how many gas explosions there have been in industrial, commercial, and residential occupancies. Even having these overall numbers would not be nearly as valuable as having an accurate breakdown on the specific fuels, equipment, and explosion protection measures employed, as well as the size of the loss in terms of casualties and property damage.

Multi-company U.S. industry sponsored projects are underway on one or two explosion topics, such as vapor cloud explosions. The problem with this ad hoc approach entirely under the auspices of one or two specialized industries is that the research objectives tend to be short-sighted, the research is conducted only by one or two private research organizations, and publication of the results is either suppressed or substantially delayed. These are a far cry from the coordinated and widely reported research projects underway with European Union sponsorship of government-industry-university explosion research teams.

Conclusions

Although explosions contribute significantly to annual U.S. fire losses, it is not currently possible to quantify that contribution with any accuracy. The primary reasons for our lack of reliable data on U.S. explosion incidents are that the fire reports filled out using forms such as NFPA 901 do not explicitly account for explosion incidents, and the explosion loss data collected by insurers and by certain government agencies are very narrow in scope and in the number of facilities and personnel at risk. Without an accurate and broad-based national database, we cannot decipher the current level of success being experienced with existing explosion prevention and explosion mitigation technology and practices, let alone decipher any changes to that level of success. It is important to develop such a database.

The United States has fallen behind other parts of the world (particularly Europe) in the development and utilization of new explosion protection technology. Our fall from a leadership position is due in part to the U.S. shortfall in suitable explosion testing and research facilities, and in part to the extensive European Union sponsorship of coordinated government-industry-university explosion research programs. In order to re-establish U.S. leadership, there is a need for the same type of coordinated collaborative explosion research programs that are now common in Europe and Asia.

There is a need for research in the following specific explosion issues: 1) flame speeds in highly non-uniform gas-air mixtures, 2) deflagration-to-detonation transitions in congested and turbulent environments, 3) dust cloud formation that can lead to dangerous secondary dust explosions, 4) blast wave propagation in buildings, and 5) blast wave generation of secondary fragments and the development of blast resistant/compliant windows.

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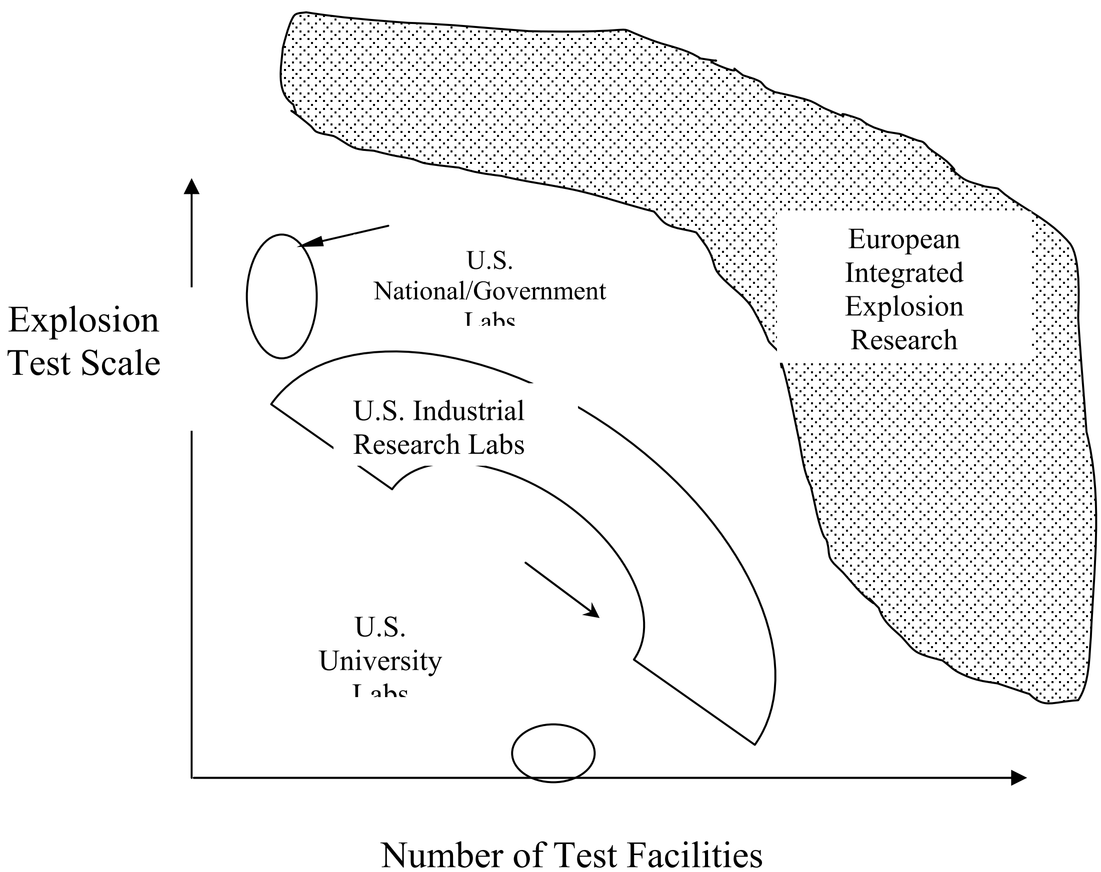

Figure 1. Conceptual Comparison of Explosion Testing Facilities in U.S. and Europe.

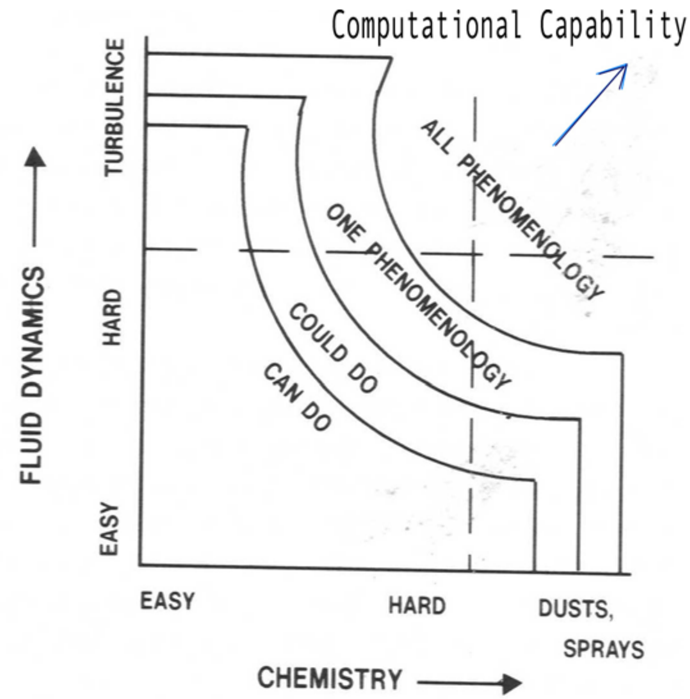

Figure 2 CFD Requirements for Explosion Simulations (adopted from Oran et al, 1982)

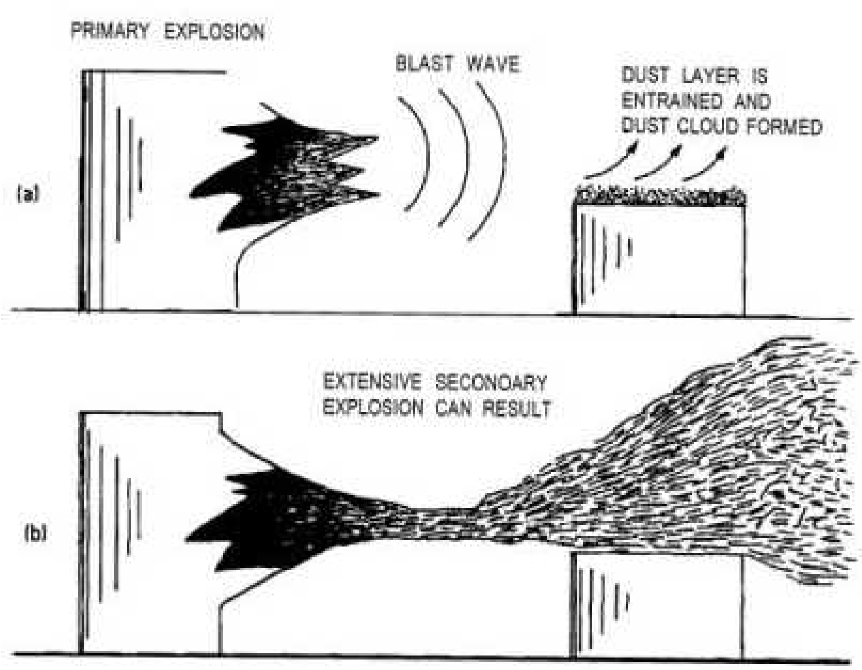

Figure 3. Secondary dust explosion caused by a) blast wave from primary explosion lifting accumulated dust, and b) flame from primary explosion igniting newly formed combustible dust cloud (from Eckhoff, 1997)

Summary of Fundamental Research Needs

F. Dryer
(07/14/02)

Current basic research is inconsistent with intent of America Burning 1974. The approximately 2 million dollar annual expenditure of the NSF Research Applied to National Need (RANN) on fundamental fire research topics in the mid 70's has dwindled to about 25 programs in 2002 supported through the NIST Center for Fire Research effort. Few of these projects concentrate on the basic aspects in the fire research area. Exemplar of the problem is that performance codes are being proposed without the necessary infrastructure, and multiple fire tests and standards are developing without a fundamental science base to remove redundancies and emphasize universality. The US cannot afford to have simply an empirical fire safety research infrastructure, and a dearth of fundamental science upon which to build new, more predictive fire modeling and performance-based design tools. The hand-off across disciplinary approaches from basic to applied research and onward into applications and development and eventually into field-use discussed by Croce in his presentation is not presently, nor has it more recently been effective. Fundamental and applied research is not interactively connected, and the connection to developers and the field is also not well coordinated. While the lack of interconnection is essentially precluded by the dearth in research funding, there is also no infrastructural organization presently active to provide the necessary communications and technology transfer. Efforts to achieve these hand-offs within the NSF-RANN program identified that a principle detractor in this process is the "language barriers" in going from fundamentals to the field. Dialogue interchange amongst fundamental data and model developers, numerical modelers, behavioral scientists, and practitioners is needed if the design of field tools is to progress. Although this process is typically painful, it is important that practitioners, applied researchers, and basic researchers interface within the fire disciplinary area. New manpower must be produced for utilizing/advancing these tools, as well as for developing the future tools; thus, an academically based fundamental research component is critical to the evolution. Such interfaces have almost entirely disappeared within the fire safety field, resulting in the present "disconnect" and nearly complete demise of basic research activity in and support of fire safety related issues. Indicative of the level to which these problems has decayed is that within the microgravity sciences programs of NASA, 10 of the principal investigations are NIST scientists involved in the Center for Fire Research. Clearly, the funding of fundamental research relevant to the fire problem is far below that required, and what remains is fragmented and tenuously supported.

NSF is likely the most appropriate agency to rejuvenate efforts and assure coupling with applied needs through approaches similar to those developed for the earthquake engineering area. If intercommunications among levels within the discipline can be strengthened, the transfer of fundamental knowledge to the field can occur in today's computer-based technological environment much more facilely than in the past. Fundamentals can be embodied within modeling tools, and advance modeling tools to real-time interactive abilities with the faster processing approaches that are continuing to evolve. It is important to realize, however, that "predictive" modeling requires continual refinement of the sub-models and fundamental descriptions within these approaches, as new and more detailed questions arise. For example, fire and smoke spread represents one level of description while toxic product evolution would require a much more sophisticated level of description. Flashover in room fire is the main contributor to death and injury of people. By slowing down the processes leading to flashover (or better preventing it to occur), more time is allowed for people to escape. The strategy is to slow down or limit the initial fire growth so that the flashover condition may not be reached. This issue represents a more complex issue than can adequately be addressed with current tools.

The "Pasteur's Quadrant" approach to research (Stokes, D.E., (1997), *Pasteur's Quadrant*, Brookings Institute Press, Washington DC; Glassman, I. (2000) Proc. Comb. Ins. 28, 1) discussed by Croce which introduces the concept of "use-inspired fundamental research" defines what should motivate all "basic or fundamental research" in engineering disciplines. It is important to note, however, that "use-inspired" basic research should still span a wide range of scales from underpinning fundamental science to the interaction of fluid transport, chemical kinetic, and heat transfer sub-models. For example, fundamental thermodynamic, thermophysical, and thermochemical property data on existing and new materials to be used in fabrication are needed to produce science-based models. Compact, but reasonably robust sub-models for chemical kinetics, molecular transport, turbulence effects and radiative transfer are needed to eventually permit the replacement of empirical heat release rate descriptions, generally input into fire models today, with an interactive fundamental description of material combustion. The large-eddy flame-spreading model in FDS from NIST has been a very useful engineering tool used by many organizations in the world. However, the necessity to use coarse grids has forced smaller-scale processes to be neglected. Sub-grid models will depend on better description of fundamental processes. These models must be appropriate for the buoyant fire situation and capable of predicting local extinction, for example.

The present fundamentals are insufficient for predicting gas-phase flame extinction issues relevant to yielding improved strategies for inhibiting inflammation, reducing rate of fire development and extinguishing fires. Laminar and turbulent extinction processes under high temperature, partially vitiated (and combustion product diluted) fuel-rich and fuel-lean conditions are poorly understood and characterized. Improved knowledge of flame speeds in highly non-uniform gas-air mixtures, deflagration-to-detonation transition in complex geometric and turbulent environments, and blast wave propagation within building constructions, garage structures, and transportation tunnels are needed. Flammability and ignition properties of vapor/aerosol mixtures as well vapor/dust mixtures must also be included within the above types of studies. Predictive capability for flame initiation, propagation and acceleration is needed for structure design. In terms of impact on residential fires, fundamentals and technology development can today produce inherently safe heating and cooking appliances, arc limited electrical systems, and further improvements in container design for liquid flammable materials.

Chemical kinetic descriptions of heterogeneous decomposition as a function of heat loading, and the gas phase species evolved are very limited, as are the thermochemical, thermophysical, and thermodynamic properties of existing flammable materials.

Describing the interactions of several materials as fuel resources for fire also needs additional fundamental underpinning. Increased understanding of methodologies to accelerate charring processes with minimal gaseous flammable evolution could lead to improved fire properties with regard to the response of materials to heat loading, to the production rate of excess pyrolyzates leading to flashover, and to the production of toxic products. A noted in the workshop papers, world-wide effort has yet to produce an effective replacement for Halon 1301. Further knowledge of the detailed mechanisms that lead to inhibition by I, P,Mn, Sn, Si, Ge, As, Sb, Ti, Sn, Cu, Cr, and Pb is needed.

As the very fundamental level of research develops, more applied, empirical descriptions of oxidative degradation and pyrolysis mechanisms of materials need to be further evolved to yield adequate short-term model inputs, as well as to characterize experimental results that can be used to eventually validate and refine the more fundamental descriptions as they evolve. Utilization of new applied mathematical approaches to perform global feature sensitivity analyses at the fundamental level as well as on large-scale systems will be critical to evaluating and directing model developments.

SIMULATING ENCLOSURE FIRE DYNAMICS

Howard R. Baum [1]

Abstract

At least three different physics based approaches to fire dynamics simulations have evolved over the years; lumped parameter or "zone models", computational fluid dynamics models based on classical turbulence modeling techniques, and large eddy simulations. Large eddy simulations provide the most realistic description of fire phenomena developed to date. All such simulations provide descriptions of the processes that control the mixing and combustion of fuel and air at elevated temperatures. In an enclosure fire these processes are complicated by the fact that the fuel was initially part of the building or its furnishings, and the air supply is controlled by the interaction of the fire with its surroundings. The geometry of the building and its furnishings all influence the fire and are in turn changed by it. The rational prediction of these changes is one of the central issues of fire research. The key to understanding these phenomena lies at the interface separating the gas and condensed matter phases. Substantial institutional barriers hamper progress in this area of research.

Introduction

The idea that the dynamics of a fire might be studied using digital computers probably dates back to the beginnings of the computer age. The concept that a fire requires the mixing of a combustible gas with enough air at elevated temperatures is well known to anyone involved with fire. Graduate students enrolled in courses in fluid mechanics, heat transfer, and combustion have been taught the equations that need to be solved for at least as long as computers have been around. What is the problem? The difficulties revolve about three issues: First, there are an enormous number of possible fire scenarios to consider. Second, we do not have either the physical insight or the computing power (even if we had the insight) to perform all the neccessary calculations for most fire scenarios. Finally, since the "fuel" in most fires was never intended as such, both the data and the models needed to characterize both the fuel and the fire environment may be unavailable or unknown or both.

In order to make progress, the questions that are asked have to be greatly simplified. To begin with, instead of seeking a methodology that can be applied to all fire problems, we begin by looking at a few scenarios that seem to be most amenable to analysis. Hopefully, the methods developed to study these "simple" problems can be generalized over time so that more complex scenarios can be analyzed. Second, we must learn to live with idealized descriptions of fires and approximate solutions to our idealized equations. These idealized descriptions have to be based on the kind of incomplete knowledge of fire scenarios that is

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characteristic of real fires. Finally, the methods should be capable of systematic improvement. Thus, as our physical insight and computing power grow more powerful the methods of analysis can grow with them.

These issues have to be faced by anyone seeking to develop simulations of fire dynamics. Inevitably, different research groups have come to widely varying conclusions about how to proceed. The first effective simulations of fire dynamics were based on "zone models". Each compartment is divided into two spatially homogeneous volumes, a hot upper layer and a cool lower layer. Mass and energy balances are enforced for each layer, with additional models describing other physical processes appended as differential or algebraic equations as appropriate. Examples of such phenomena include fire plumes, flows thru doors, windows and other vents, radiative and convective heat transfer, and solid fuel pyrolysis. An excellent description of the physical and mathematical assumptions behind the zone modeling concept is given by Quintiere (1984). The relative physical and computational simplicity of the zone models has led to their widespread use in the analysis of fire scenarios. So long as detailed spatial distributions of physical properties are not required, and the two layer description is a reasonable approximation to reality, these models are quite reliable. However, by their very nature, there is no way to *systematically* improve them.

The rapid growth of computing power and the corresponding maturing of computational fluid mechanics (CFD), has led to the development of CFD based "field" models applied to fire research problems. Virtually all this work is based on the conceptual framework provided by the $k-\epsilon$ turbulence modeling approach pioneered by Spalding and his collaborators. The CFD based approach has rapidly led to the development of software packages aimed specifically at fire problems. The now-classic investigation of the London Kings Cross Underground Station fire involved the use of what is now known as CFX4. The CFD portion of the investigation (Simcox et al. 1992) was a landmark in the use of this methodology in fire research. The prediction, subsequently confirmed by scale model experiments, of the "trench effect" (a Coanda effect for fire plumes in confined inclines like the escalator banks in the Kings Cross fire) led to greatly increased acceptance of field modeling in fire research. More recently, SOFIE (Lewis et al. 1997) was developed under the guidance of a consortium of European fire research organizations; a brief summary of the rationale and goals of the project is given by Moss and Rubini (1997). This description is certainly not comprehensive; a complete listing of the available CFD codes that have been used in fire research is beyond the scope of this paper.

The use of CFD models of the type described above has allowed the description of fires in complex geometries, and the incorporation of a wide variety of physical phenomena. However, these models have a fundamental limitation for fire applications; the averaging procedure at the root of the model equations. The $k-\epsilon$ model was developed as a time averaged approximation to the conservation equations of fluid mechanics. While the precise nature of the averaging time is not specified, it is clearly long enough to require the introduction of large eddy transport coefficients to describe the unresolved fluxes of mass, momentum and energy. This is the root cause of the smoothed appearance of the results of even the most highly resolved fire simulations. The smallest scale flow induced details that are computable are determined by the product of the local velocity and the averaging time underlying the $k - \epsilon$ model, rather than the spatial or temporal resolution of the computation.

Unfortunately, the evolution of large eddy structures characteristic of most fire plumes is lost with such an approach, as is the prediction of local transient events. It is sometimes argued that the averaging process used to define the equations is an "ensemble average" over many replicates of the same experiment or postulated scenario. However, this is a moot point in fire research since neither experiments nor real scenarios are replicated in the sense required by that interpertation of the equations. In practice, the $k - \epsilon$ model provides a much richer description of the spatial evolution of a fire scenario than can be obtained with a zone model. However, there is little difference in the temporal resolution achieved by this approach.

Large Eddy Simulations

The "Large Eddy Simulation" (LES) technique developed at NIST over a nearly two decade period is our attempt to carry out the conceptual program outlined above. The phrase refers to the description of turbulent mixing of the gaseous fuel and combustion products with the local atmosphere surrounding the fire. This process, which determines the burning rate in most fires and controls the spread of smoke and hot gases, is extremely difficult to predict accurately. This is true not only in fire research but in almost all phenomena involving turbulent fluid motion. The basic idea behind the use of the LES technique is that the eddies that account for most of the mixing are large enough to be calculated with reasonable accuracy from the equations of fluid mechanics. The hope (which must ultimately be justified by appeal to experiments) is that small scale eddy motion can either be crudely accounted for or ignored.

The equations describing the transport of mass, momentum, and energy by the fire induced flows must be simplified so that they can be efficiently solved for the fire scenarios of actual interest. The general equations of fluid mechanics describe a rich variety of physical processes, many of which have nothing to do with fires. Retaining this generality would lead to an enormously complex computational task that would shed very little additional insight on fire dynamics. The simplified equations, developed by Rehm and Baum (1978), have been widely adopted by the larger combustion research community, where they are referred to as the "low Mach number" combustion equations. They describe the low speed motion of a gas driven by chemical heat release and buoyancy forces.

The low Mach number equations are solved on the computer by dividing the physical space where the fire is to be simulated into a large number of rectangular cells. In each cell the "state of motion", i.e. the gas velocity, temperature, etc. are assumed to be uniform; changing only with time. The computer then computes a large number of snapshots of the state of motion as it changes with time. Figure 1 shows one such snapshot of a hangar fire simulation. Clearly, the accuracy with which the fire dynamics can be simulated depends

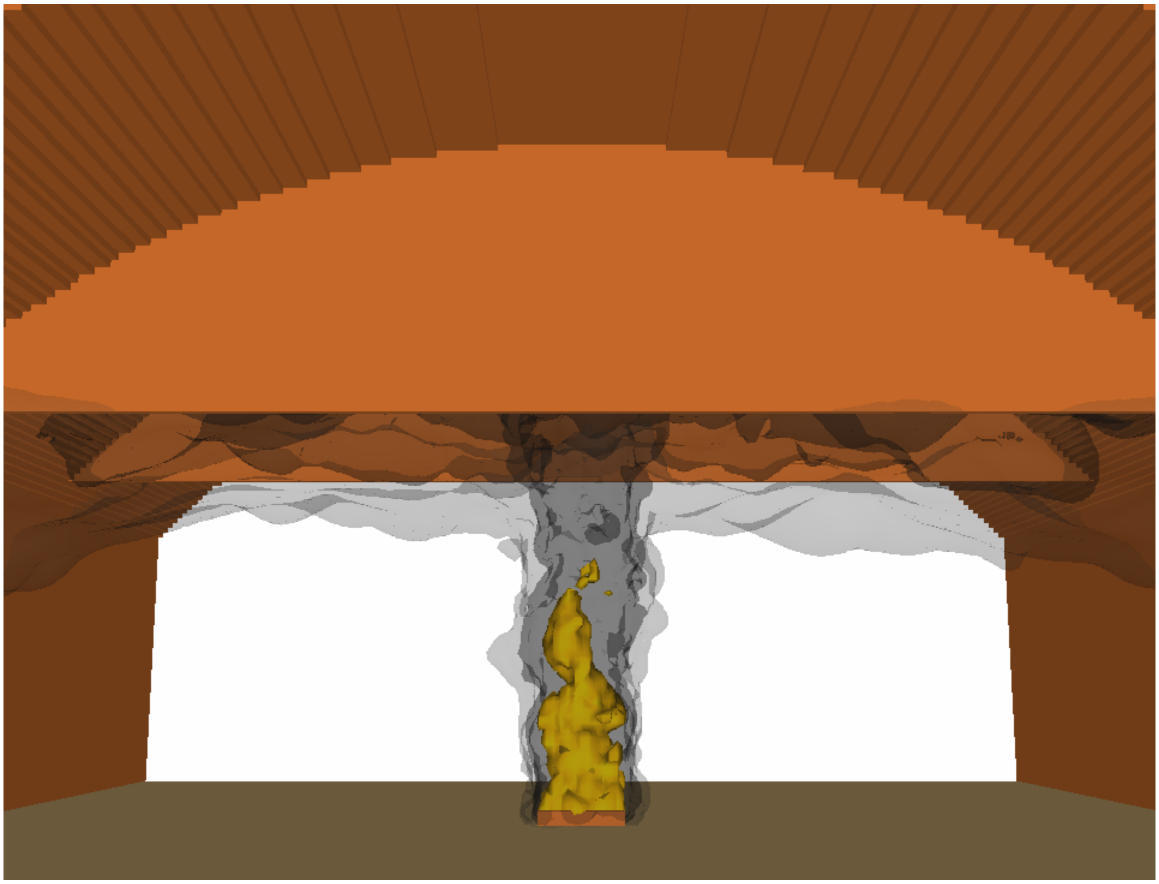

FIGURE 1: Snapshot of a simulation of 3 m square jet fuel fire in a 22 m high and 45 m wide aircraft hangar. Contours corresponding to the mean flame temperature maximum and the highest temperature non-burning region are shown.

on the number of cells which can be incorporated into the simulation. This number is ultimately limited by the computing power available to the user. Present day computers limit the number of such cells to at most a few million for an individual processor. This means that the ratio of largest to smallest eddy length scales that can be resolved by the computation (the "dynamic range" of the simulation) is roughly $100 \sim 200$. Massively parallel supercomputers are excluded from this estimate, but their existence has played no role in the development of fire research to date. Unfortunately, the range of length scales that need to be accounted for if all relevant fire processes are to be simulated is roughly $10^4 \sim 10^5$. Much of the discrepancy is due to the fact that the combustion processes that release the energy take place at length scales of 1 mm or less.

The idea that different physical phenomena occur at different length and time scales is central to an understanding of fire phenomena, and to the compromises that must be made in attempting to simulate them. The most important example is an isolated fire plume in a large well ventilated enclosure (see fig. 1). Simulations of scenarios of this kind are reported in Baum et al. (1996). The fire plume is the "pump" which entrains fresh air

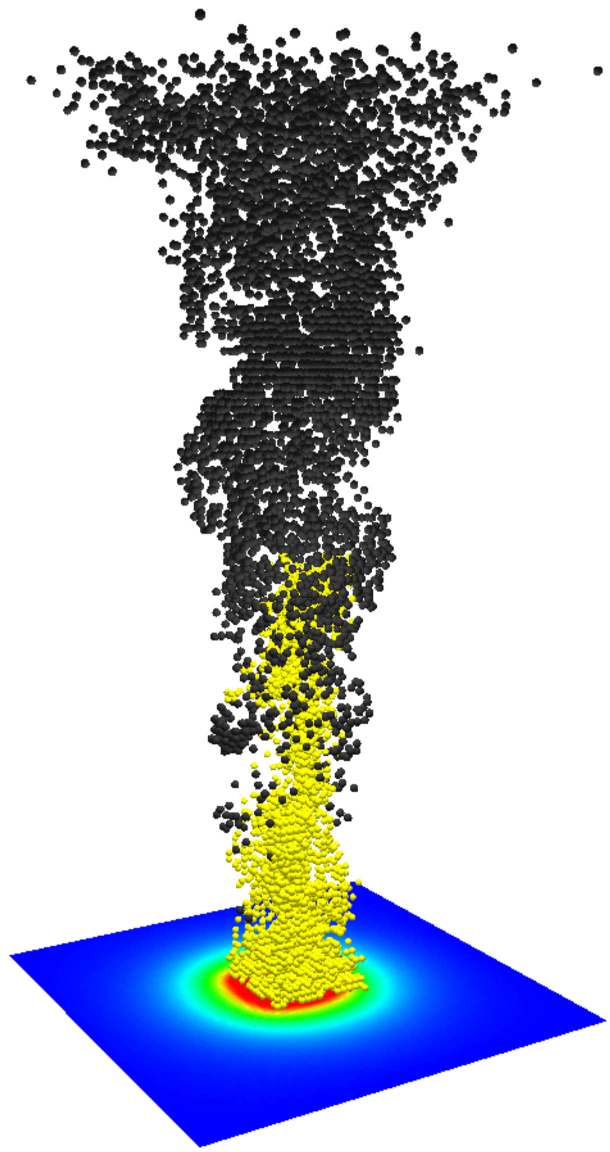

FIGURE 2: Snapshot of isolated plume structure showing burning elements (light color), burnt out combustion products (dark color), and radiation heat flux contours to fuel bed.

and mixes it with the gasified fuel emerging from the burning object. It then propels the combustion products through the rest of the enclosure. The eddies that dominate the mixing have diameters that are roughly comparable to the local diameter of the fire plume. Thus, in the above simulation, the cells have to be small enough so that many (a 12x12 array in this case) are used to describe the state of motion across the surface of the fuel bed. Since the simulation also needs to include the remainder of the hangar as well, even the 3 million cell simulation shown in Fig. 1 above cannot cope with the combustion processes without additional modeling effort.

Physical processes like combustion that occur on scales much smaller than the individual cell size are often called “sub-grid scale” phenomena. The most important of these for our purposes are the release of energy into the gas, the emission of thermal radiation, and the generation of soot together with other combustion products. These phenomena are represented by introducing the concept of a “thermal element” (Ezekoye et al. 1994). This can be thought of a small parcel of gasified fuel interacting with its environment. The concept is illustrated in Figure 2.

Each element is carried along by the large scale flow calculated as outlined above. As long as the fire is well ventilated, it burns at a rate determined by the amount of fuel represented by the parcel and a lifetime determined by the overall size of the fire. The lifetime of the burning element is determined from experimental correlations of flame height developed by McCaffrey (see Baum and McCaffrey 1989). A prescribed fraction of the fuel is converted to soot as it burns. Each element also emits a prescribed fraction of the chemical energy released by combustion as thermal radiation. This fraction is typically about 35 percent of the total. The soot generated by the fire can act as an absorber of the radiant energy. Thus, if the fire generates large amounts of soot, the transport of radiant energy through the gas must be calculated in detail . Even in the absence of significant absorption of radiant energy by the products of combustion, the radiant heat transfer to boundaries is an important component of the total heat transfer to any solid surface. Figure 2 shows a snapshot of the elements used to simuate an isolated fire plume in the absence of any boundaries. Time averages of the output of this kind of simulation must be produced in order to make quantitative comparison with most experimental data. Indeed, it is the fact that the *results* of the simulation can be averaged in a routine way while the *equations* of fluid mechanics cannot is the basis of the whole approach presented here.

The ideas outlined above have been gathered together and implemented in a publically available computer code *Fire Dynamics Simulator* (FDS) developed by McGrattan and Forney (see McGrattan et al. 2000). It has been used by hundreds of researchers and fire protection engineers around the world. An evaluation of its capacity to simulate pool fires (Joulain 1998) was summarized as follows:

> “Their computations primarily showed that large scale fire dynamics and smoke movement can be accurately calculated directly from the fundamental equations. The great ability of this approach clearly appears in (Fig. 4). At present, it can be said that the limitations of this approach have more to do with the incorporation of other physical processes like fuel pyrolysis rate, combustion model, and radiation transport than with further improvements of the description of the turbulent mixing.”

Research Needs

The limitations expressed above are very real. The fundamental properties of turbulent flow phenomena in general and turbulent combustion in particular are still poorly understood, and likely to remain so for decades to come. An improvement in the calculation of radiative transport and the combustion energy release has been incorporated in FDS (Version 2). The crude analytical calculation of the radiative transport in the original version of FDS has been replaced. The new numerical scheme accounts for both the spatial and wavelength dependence of the thermal radiation by averaging the equation governing the transport of radiant energy over each computaional cell and dividing the energy spectrum into a discrete number of broad bands. The thermal elements have been replaced with a mixing controlled model of combustion, where the energy release rate is related to the local oxygen consumption rate. The oxygen consumption is calculated by assuming that fuel and oxygen react infinitely fast when they come into physical contact. The resulting "mixture fraction" model evaluates a passive scalar quantity (the mixture fraction) which determines the degree of mixing between fuel and oxygen in each grid cell. Details can be found in McGrattan et al. (2001). These models are too new to provide any realistic evaluation of their ability to cope with fire scenarios, but they are unlikely to be the last word in these subjects.

However, even with these improvements, the basic uncertainties associated with turbulence phenomena remain unresolved. Specifically, the combustion energy release rate is controlled by small sub-grid scale mixing processes even for a well ventilated fire. The local emission of radiant energy is strongly influenced by small scale fluctuations in the temperature and the amount of soot generated by combustion. Both these topics are subjects of intense research in the combustion community. If the fire is poorly ventilated, the details of combustion chemistry become important. This too is an important research issue in combustion science, made more complex here by the uncertain characteristics of the "fuels", gasified building or furnishing materials. It is unlikely that fire research (as opposed to fundamental combustion research) is the proper venue for such studies. The fire research community has long been a borrower of ideas generated in other research areas, and will probably remain so with respect to the phenomena discussed above.

The problems peculiar to fire research that most need addressing occur at the interface between the gas and condensed phase materials. The research issues arise in both phases, and are difficult to separate. Figure 3, an early attempt by R. Rehm to simulate the fire in one of the World Trade Center towers, gives some indication of what is needed.

First, the geometry and constuction materials of the building need to be defined. If the representation of the building is simple enough, this can be done manually from building plans or other information. That is what was done here. However, the geometry used in this simulation (which is a crude representation of several floors of the damaged structure) is at about the limit of what can be done without an electronic interface between the computer codes that execute the fire simulation model and those used to design it (if any). The last caveat is quite important, since most buildings in existence today were built without the assistance of computer aided design, and this situation will remain true for decades.

Next, it is neccessary to have some idea of the building contents, their distribution

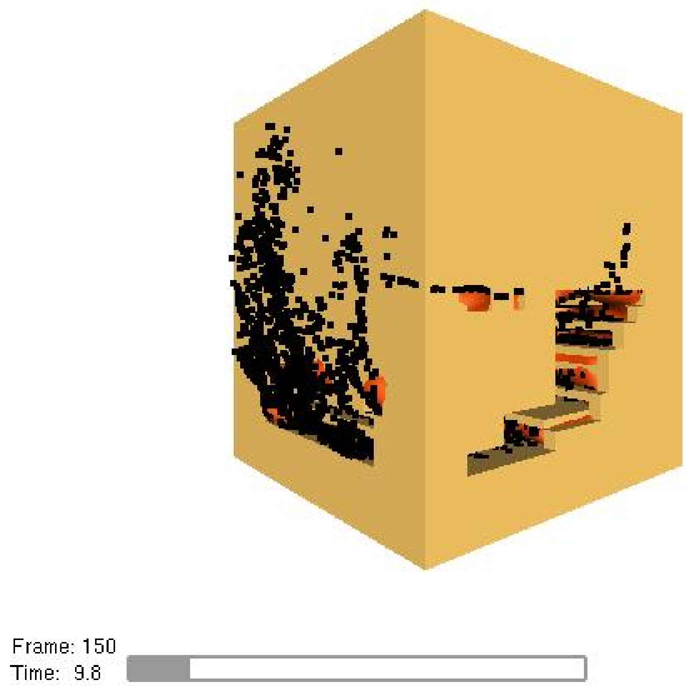

FIGURE 3: Snapshot from World Trade Center fire simulation showing smoke and flame emerging from damaged structure. (Courtesy R. Rehm)

within the building, and their material properties. While fire simulations typically consider wood cribs and combustible wall linings, any space intended for human occupation contains a rich variety of objects capable of sustaining a fire. Any substantial piece of furniture, for example, is itself a complex assembly of different materials, whose burning behavior is determined as much by their geometric arrangement as by their thermochemical properties. However, once a furniture object begins to burn, its geometry will undergo rapid change, which can influence not only the rate at which the object will burn, but its propensity to ignite other objects nearby. There has certainly been a considerable amount of furniture fire testing. However, there have been few studies oriented towards a systematic way of characterizing furniture so that the techniques used in heat transfer, combustion, and material science can be brought to bear on this problem.

Finally, the underlying geometry of the building can be altered by the fire. While most of the openings in the idealized representation in Figure 3 were caused by the initial impact of the aircraft, much of the air supply needed to sustain the fire was caused by window breaking. Although a good start has been made on this issue (see Joshi and Pagni 1994), much remains to be done. The fire changes to the building geometry alter the air supply in other ways as well. Many non-structural partitions undergo considerable warping under thermal loads, even if the materials are not combustible. While the direct impact on the structural integrity of the building may be negligible, the changes in air supply to the fire can alter its subsequent behavior.

Obviously, the fundamental technical issue in the world trade center collapse is the precise nature of the role played by the fires. While it is far to early to make any definitive statements, the very fact that the issue has been raised leads to questions about our ability to make predictions of fire induced structural collapse, even assuming that the damage caused by the initial crash was known in detail. Most large buildings are complex assemblies of steel and concrete, with protective coatings over steel surfaces. How these complexes behave at elevated temperatures, and to what extent they influence the fire behavior, is a difficult subject in its own right. Little research in this area has been carried out in the U.S. for two decades. The perception among many fire protection engineers is that this subject is well understood. Whether that opinion is shared by researchers in structural mechanics and materials science is an open question.

Insitutional Barriers

The institutional barriers to carrying out research in these areas are considerable. Problems involving turbulent combustion and its related issues have long been studied by the combustion community. However, the motivation for most of this research has been the improvement of efficiency in industrial processes and powerplants. This implies a certain degree of control over the process, and leads to many assumptions about the kind of information that will be available and the level of detail worth pursuing in any investigation. Fire, by contrast, is essentially uncontrolled combustion. Any attempt to overly constrain the processes under investigation, or postulate excessively detailed descriptions of phenomena, will prove counterproductive. They will provide information for combustion science, but not for fire research.

There have been many investigations of the thermal degradation of solids that consider an individual material in isolation. However, there is no systematic approach to the analysis of assemblies of materials. Indeed, there is no consensus as to what level of detail is appropriate for the study of thermal breakdown of individual materials. In the absence of either a conceptual framework for the analysis of complex objects under fire load, or an agreed basis for the study of individual materials, it is not clear which community "owns" this problem. Many in the fire research community think it is a non-issue, that can be addressed by the systematic improvment of synthetic "fire data" sets which provide numerical parameters for existing fire models. In the short term, this may appear to provide the best payoff for limited research funds. However, in the long term it is a recipe for the systematic elimination of fire research as a field to be taken seriously by the scientific community.

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FIRE PROTECTION SYSTEMS: ALTERNATIVE SENSORS

Susan L. Rose-Pehrsson[1]

ABSTRACT

Better sensing methods providing more sensitivity and faster responses are needed to detect fires early before they become a major problem. Work place monitoring for hazardous chemicals and indoor air population have become concerns. It would be advantageous to have a detection method that could be used for monitoring hazardous chemicals and conditions in addition to providing fast, reliable fire detection. The Early Warning Fire Detection System consisting of four commercial sensors in an array with a probabilistic neural network has demonstrated the advantage of a multicriteria approach to fire detection. The EWFD system provides fast responses to both flaming and smoldering fires with high nuisance source immunity. The next step towards improved fire sensors and sensor arrays are smart microsensor arrays. Alternative methods for fire detection are being investigated by a number of companies. The sensor types vary, but the desired characteristics are the same. Sensors and sensor systems are desired that are small, low power, robust, reliable and low cost. Methods currently under development have the potential to reduce the cost, extend the performance to include other important analytes and provide high temperature operation. Small, low cost systems allow for larger sensor networks further improving fire detection.

Introduction

Improved fire safety requires fast, reliable fire detection systems with automated fire suppression. Detectors are needed that will rapidly respond to both flaming and smoldering fires while not alarming for common nuisance sources. More reliable fire detection systems will also allow automatic control of fire suppression systems, thus minimizing damage. In addition, the ability to discriminate between fires and their byproducts (spreading fire rather than spreading smoke) would be beneficial for efficient distribution of manpower and resources. The most promising means of improving fire detection systems is through a multicriteria approach. The multicriteria approach to fire detection was demonstrated using various combinations of commercial sensors in arrays with a probabilistic neural network. (Gottuk, 1999, Rose-Pehrsson 2001) A prototype using a four-sensor array consisting of ionization and photoelectric smoke detectors and carbon monoxide and carbon dioxide sensor has been extensively tested. Compared to commercial smoke detectors, this Early Warning Fire Detection System (EWFD) was demonstrated to provide faster responses to both flaming and smoldering fires with a higher nuisance source immunity. (Gottuk, 1999, Rose-Pehrsson, 2001, Wright, Hart, Gottuk, 2002, Rose-Pehrsson, 2002)

More than a decade ago, the concept of mimicking the human nose with semi-selective sensor arrays coupled with multivariate data analysis methods gave birth to the idea of generating an electronic nose. Today, both electronic noses and electronic tongues can be found at popular trade shows. Microsensor arrays are being marketed for

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a variety of chemical problems. Recently, several companies are investigating the new sensor array systems or electronic noses for indoor air monitoring and early fire detection. (SamDetect, General Atomics, KAMINA, Cyranose) Several different sensor technologies are applicable to fire detection including, metal oxide, cermet, surface acoustic wave devices, and conductive polymer sensors. These new approaches have the potential of providing small, low cost systems that are capable of extending the performance of fire detection systems to vapor monitoring. Networks of sensors also become more feasible with small, low cost sensors. At least one of these new sensor methods can provide detection capabilities at high temperature.

Electronic Nose Concept

Driven by the need for small, portable, inexpensive instruments that can be adapted to many detection problems, electronic nose instruments were conceived. Several factors contributed to bring this about, including (1) microfabrication and micromachining techniques to fabricate sensor structures, (2) increasing interest in chemical detection for workplace monitoring, personnel protection, and process control, and (3) the increasing sophistication and decreasing size of digital components and instrumentation capable of operating sensors or using the information they provide. Electronic noses try to mimic the human nose by grouping nonspecific sensors into an array, the signal provided by the sensors are collected, preprocessed and then a pattern recognition method is used to identify a response of interest. Figure 1 schematically describes the parts of an electronic nose. Typical sensors consist of a transducer to convert chemical information into an electronic signal and a chemically selective material to interact with chemicals of interest. When chemicals are sorbed into the coating, the mechanism of the sensor or transducer is perturbed. Most individual microsensors lack the necessary specificity, but an array of sensors with different semi-selective coating can be designed where each coating responds differently to a set of chemical vapors. The combination of sensors selected to interact with different chemical properties produce a unique fingerprint for each vapor. The sensors encode chemical information about the vapors in a numerical form, which can then be analyzed by pattern recognition methods.

Pattern recognition techniques, as applied to multi-criteria or multi-sensor systems, use sensor responses to encode chemical/physical information about the by-products of a fire in numerical form. Each sensor defines an axis in a multidimensional space. Different types of fires or events can be represented as points positioned in this space according to sensor responses. Fires that produce similar responses from the set of sensors will tend to cluster near one another in space. Pattern recognition uses multivariate statistics and numerical analysis to investigate such clustering and to elucidate relationships in multidimensional data sets. Mathematical boundaries between event types can be defined and used to identify fires and discriminate nuisance sources.

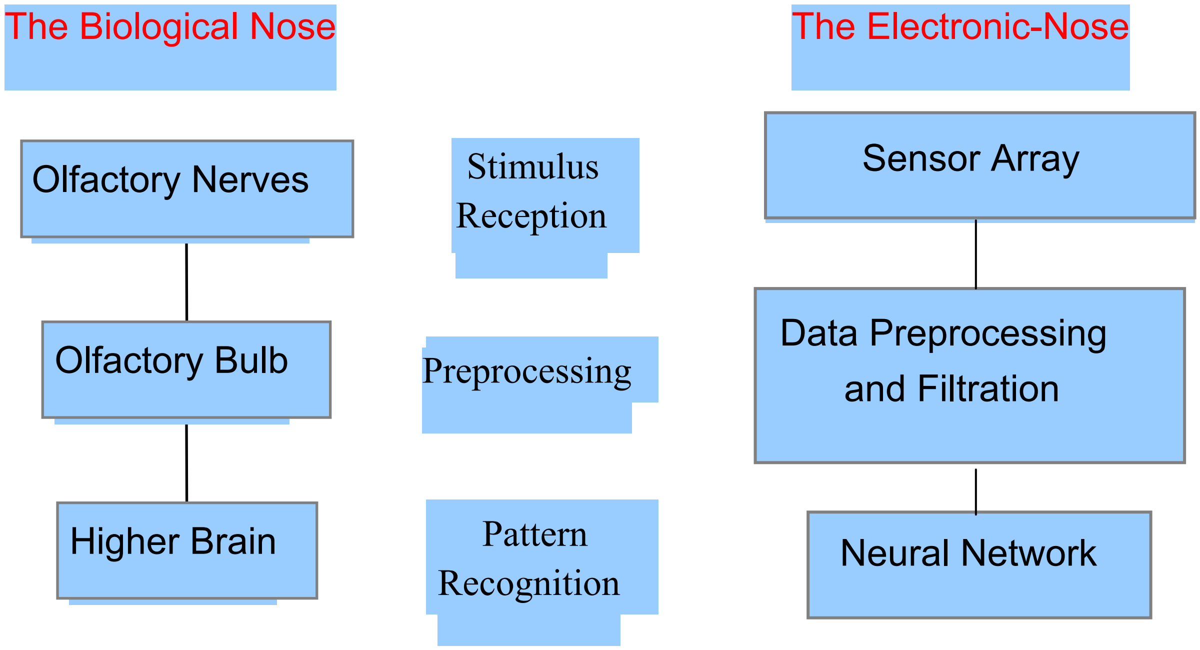

Figure 1. Comparison of electronic nose with biological nose.

Sensor Types

There are a variety of sensor types that can be used in electronic noses and can be applied to fire detection. Table 1 lists some of the types.

Table 1. Various Microsensors and Their Mechanisms for Response

Sensor Types	Function
Chemiresistor, Interdigitated Array	Conductivity
Conductive Polymer	Conductivity
ChemFET	Work Function
Fiber Optic/Wave Guide	Absorption
SAW/ QCM	Microgravimetric
Metal Oxide Semiconductor Sensor	Conductivity
Cermet	Electrochemical

Metal oxide semiconductor (MOS) sensors are one of the microsensors that have been investigated for fire detection and are currently incorporated in a commercial fire detection system. (SamDetect, Daimler-Benz Aerospace) The MOS can be used to measure a variety of toxic or combustible gases including carbon monoxide, nitrogen dioxide, sulfur dioxide, and methane. As shown in Fig. 2, the MOS sensing elements consist of a semiconductor such as tin oxide (SnO_2) sandwiched between two electrodes. In clean air, the conductivity is low. When exposed to reducing gas such as carbon monoxide, the conductivity increases. Selectivity to a particular gas is achieved by varying the temperature of the sensing element and the metal oxide layer. Metal oxide sensors are sensitive to toxic gases in the low parts-per-million range. The limitations of the devices are the potential for false positive alarms and effects of humidity on the sensor outputs.

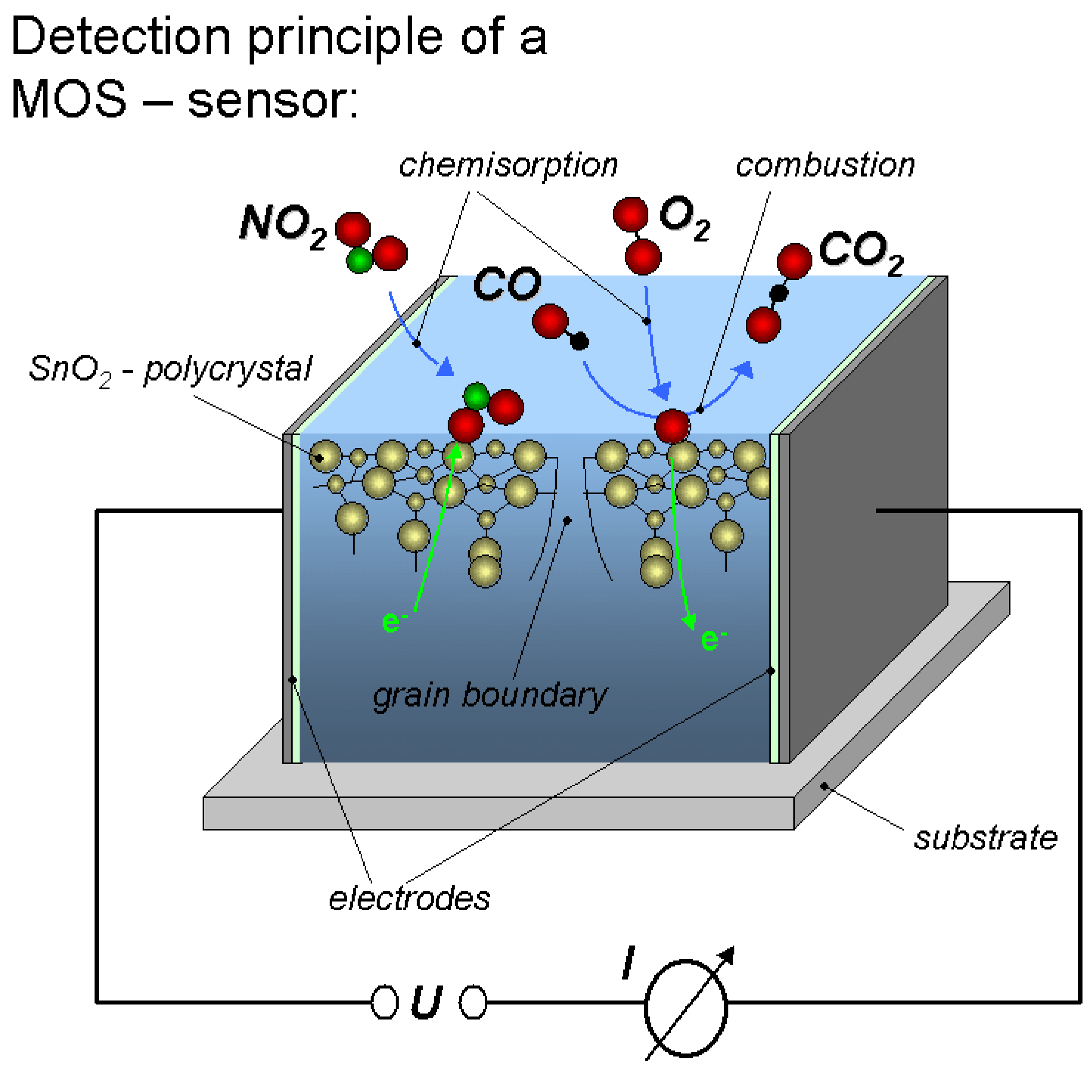

Figure 2. An example of the mechanisms involved in the sensing of chemical vapors with Metal Oxide Semiconductor Sensor.

While there are several microsensor technologies that would be applicable to fire detection, three promising methods will be described here. The sensor arrays each use a different sensor element with its own unique properties.

General Atomics – Smart Microsensor Array

General Atomics has been developing a fire detection system under the Navy's Program Damage Control Automation for Reduced Manning (DC-ARM). Voltammetric-electrocatalytic (V/EC) microsensors consisting of thick-film fabricated devices composed of various ceramic metallic (cermet) films are being used. Prototypes have been produced with both single elements and arrays. The Fig 3 below illustrates several microsensor types including the array type(s) used for fire and nuisance tests. The ceramic metallic microsensor array used was composed of four sensor elements, three of which were monitored for fire testing. The sensor elements are referred to as S0, S1, and S2 with the following compositions:

S0: tungsten bismuth oxide/platinum (WBO/Pt) (otherwise called *Sensor 1*)
S1: yttria stabilized zirconia/platinum (YSZ/Pt) (otherwise called *Sensor 2*)
S2: yttria stabilized zirconia/palladium (YSZ/Pd) (otherwise called *Sensor 3*)

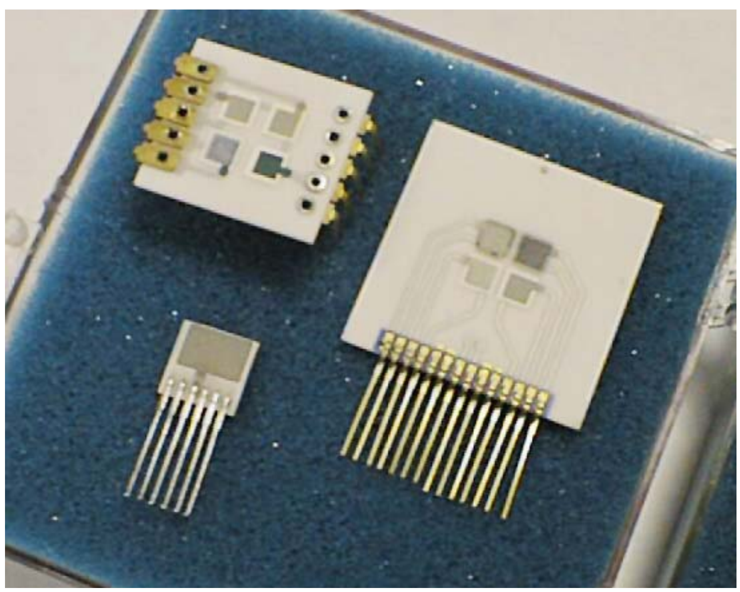

Figure 3. Cermet sensors and sensor arrays used by General Atomics.

Each sensor produced a different response to each of the test atmospheres (analytes), and the *composite array* response provided information for robust and complete classification of the samples.

The V/EC microsensor employs an electrochemical (voltammetric) measurement technique to generate its complex response waveform. Voltammetry involves applying a varying potential (typically a +/- triangular waveform) across an electrochemical cell and measuring the resultant current produced. (Chemical Sensors) The presence or absence of an analyte gas will influence the electrical characteristics of the cell (current vs. voltage). (Bard and Faulkner) Electroactive species react during both the applied waveform reduction sweep and the following oxidation sweep. This regeneration of the electroactive species allows continued reuse of the device as a sensor. The voltammetric response can be tuned by altering how the voltage is applied and the operating temperature of the cell. Voltammetry is a very well established chemical analysis technique that is particularly flexible and capable of very low level detection (part per billion) for organic, metallic, and organometallic substances. (Smythe)

Under the DC-ARM program, a breadboard system was fabricated and tested that contained an onboard power supply and temperature control. The system is shown in Fig 4. Data was collected for a set of fire and nuisance sources. The sensors were trained using the fire/nuisance data and a neural network was used to predict a subset of the sources. The preliminary results were encouraging. In addition, all the components of the breadboard system have been tested up to 300°C. (Ziegler)

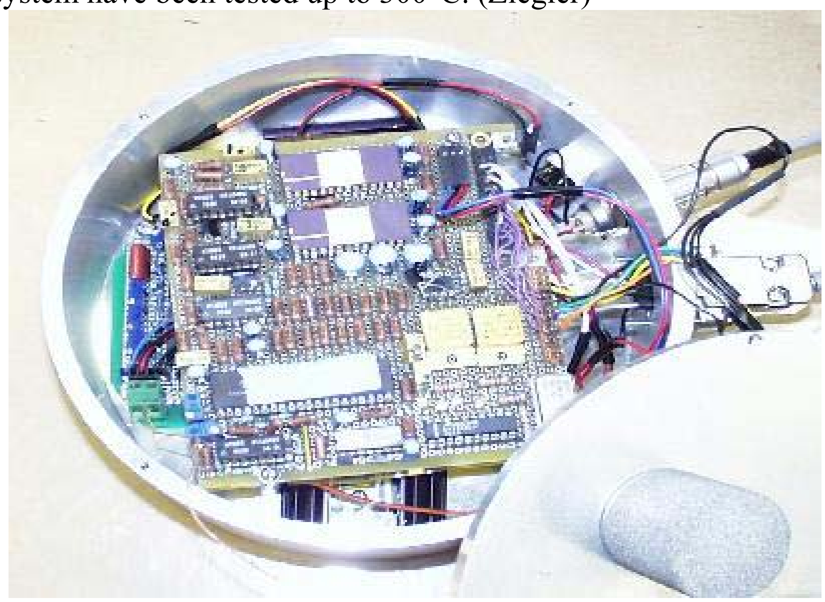

Figure 4. General Atomics Breadboard for an array of cermet sensors.

The successful completion of this system would provide the following attractive features: (1) distributed network of “smart” chemical sensors, (2) small footprint with powerful capabilities including onboard processing and decision making, (3) flexible readout electronics that could accept input from a variety of sensor types, (4) capability of sensing both toxic gases and chemical agents, (5) software that can be customized to any space, and (6) the ability to collect sensor response data allowing better discrimination than standard sensors.

KAMINA

A novel type of gas sensor microarray based on the segmentation of a monolithic metal oxide layer by a set of parallel electrodes, has been developed at the Research Center KARLSRUHE, that allows sensitive detection and discrimination of gases at a very low cost. (Harms) The single monolithic metal oxide film alone forms the basis of the whole array. This film is separated into 38 sensor segments by parallel electrode strips to measure the electrical conductivity of the individual segments. (Althainz) The necessary operation temperature (usually between 200°C and 400°C) is provided by four meandering heating elements, placed at the reverse side of the chip. The heating power is controlled by two platinum thermoresistors, placed on the upper side of the chip. The whole array is coated with a permeable SiO_2 layer of variable thickness across the 38 sensor segments.

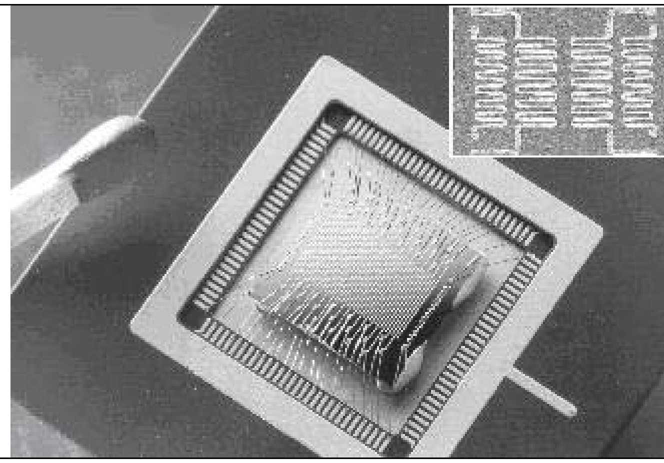

Figure 5: Gas sensor micro-array mounted in its housing. The front side consists of the metal oxide detector field, separated into 38 sensor elements by 39 electrode strips. The reverse side carries four separate heating elements (on the upper right side).

The gradient technique serves to differentiate gas detection selectivity via the 38 individual sensor segments. The thickness of the ultra-thin gas-permeable SiO_2 membrane layer deposited on top of the metal oxide film varies across the array. Additionally, a controlled temperature gradient, e.g. of 50 K, is maintained across the array. Depending on the nature of the gases, due to diffusion through the membrane and the warmth caused by gas reactions at the metal oxide interface, gas detection selectivity is gradually modified from sensor segment to sensor segment. Therefore, the exposure to single gases or gas mixtures cause characteristic conductivity patterns at this gradient microarray. The dependence of the conductivity pattern on the type and quantity of ambient gases allows gas discrimination and quantification.

This gradient microarray is used in an electronic nose system called the Karlsruhe Micro Nose (KAMINA). The micro-fabrication is uncomplicated and thus inexpensive, thus making a low cost system that is reliable, stable and sensitive to a variety of chemical species. This system is being investigated for fire detection. NASA/KSC personnel are interested in the methods for space station application. The ability to measure smoldering fires at very low concentration as well as other chemical species of interest is very attractive. Fig 6 shows some of the tests conducted using the KAMINA.

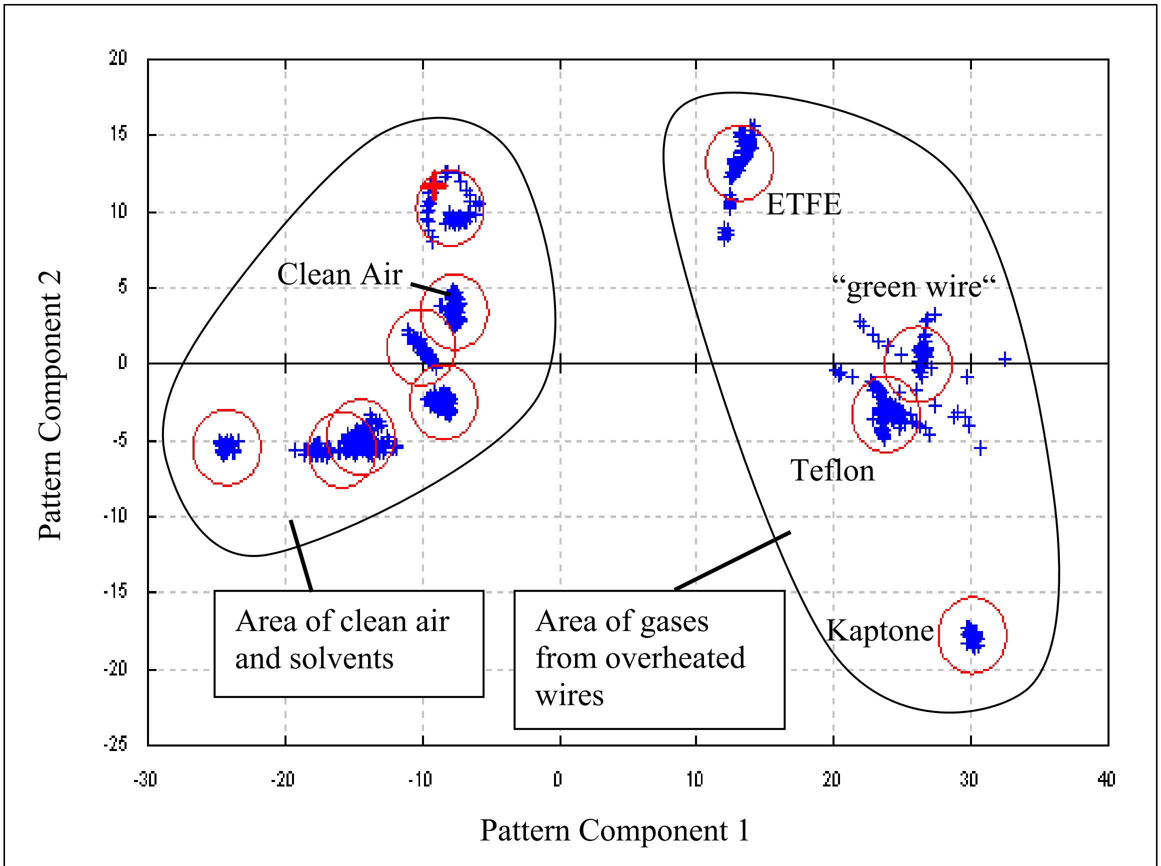

Figure 6**:** Distinction between clean air, solvents and overheated wire insulation in an LDA diagram; solvents (isopropanole, ethanole, xylene, toluene, acetone, WD40) are clearly depicted separately from pre-fire gases of hot wires mantled with kaptone, fluorine-containing and unknown materials. A gradient microarray based on Pt-doped SnO_2 was used for measurement. Its temperature was kept at 250 - 300 °C. The area limits describe a confidence range of 95 %.

CYRANOSE

Cyrano Sciences' propriety sensor technology, used in the Cyranose 320, originated in the labs of Professor Nathan Lewis at the California Institute of Technology. The technology consists of individual thin-film carbon-black polymer composite chemiresistors configured into an array. The collective output of the array is used to identify an unknown analyte using standard data analysis techniques. Each individual detector of the sensor array is a composite material consisting of conductive carbon black homogeneously blended throughout a non-conducting polymer. The detector materials are deposited as thin films on an alumina substrate each across two electrical leads creating conducting chemiresistors. The output from the device is an array of resistance values as measured between each of the two electrical leads for each of the detectors in the array. When a composite is exposed to an analyte, the polymer matrix acts like a sponge and "swells up" while absorbing the analyte. The increase in volume changes the resistance because the conductive carbon-black pathways through the material are broken. When the analyte is removed, the polymer "sponge" off-gasses and "dries out". This causes the film to shrink and the conductive pathways are reestablished. The response from the chemiresistor during an analyte exposure is measured as a bulk relative resistance change. Since an analyte will absorb into the different polymer matrices to different degrees, a pattern of response is observed across the array.

Fig 7 shows an example of an array developed and tested by Dr. Lewis. Response patterns are observed and selectivity for various gas vapors is shown in a principal component plot.

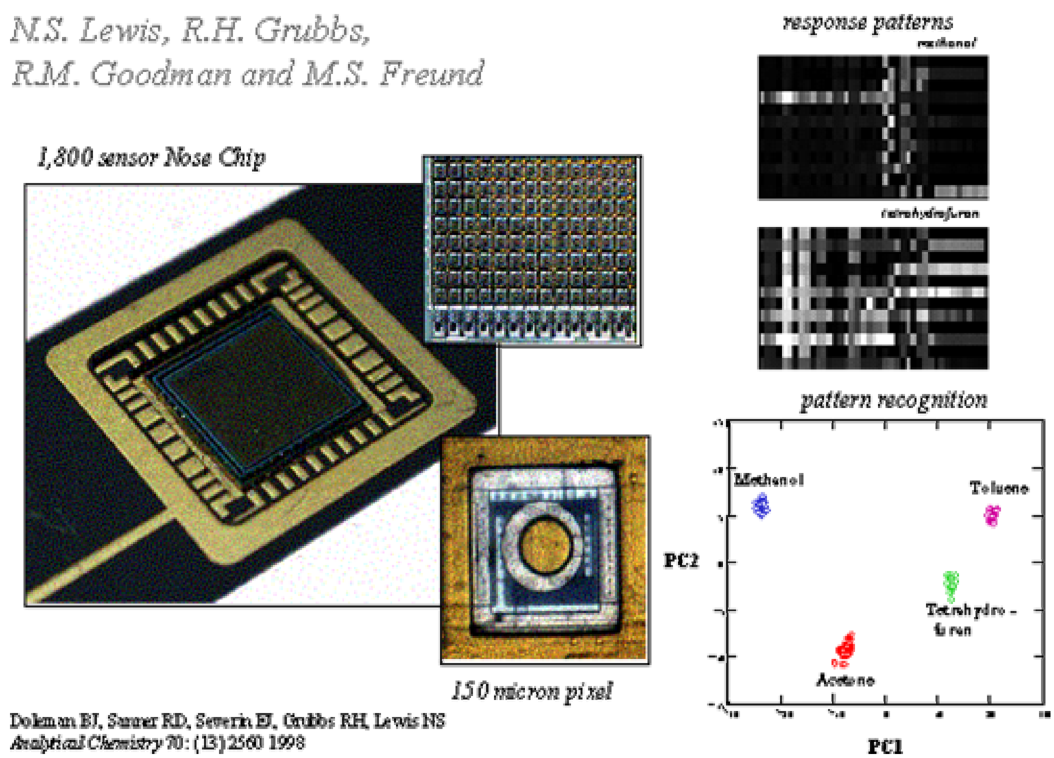

Figure 7. Good selectivity for several different vapors is clearly shown in the principal component plot for this array of chemiresistors produced by in Nathan Lewis' laboratory. Two examples of characteristic response patterns are also shown.

Conclusions

Electronic noses are being used in limited applications such as the food industry or chemical warfare detection at this time. Current limitations on sensors require highly controlled sampling or highly specific analyte detection such as chemical warfare detection. In many cases, the humidity effects are too great to be used in ambient conditions. Many of the attractive sensor technologies need better understanding of the underlying science before the responses will be completely correlated with wide variety of varying chemicals present in the ambient environment.

More mature sensors and sensor arrays are not being widely used today as fire detectors because the industry demands long-term stability and reliability. Fire detection methods are expected to operate for ten years with little or no maintenance. Methods are needed to improve sensor robustness. Alternatively better calibration schemes are needed to compensate for changes in sensors over time and varying conditions. Other techniques that would advance the technology are adaptive updating, robust modeling, fault/outlier detection and diagnostics, and sampling theory (point verses volume). New discrimination algorithms and signal processing methods are also needed.

The multicriteria approach could be extended even further to include different sensor types, expanding the orthogonality of information generated. Sensor systems could also begin to mimic "man" by combining a variety of different senses similar to man's eyes, ears, nose, and touch. A new ONR program, "Advanced Damage Countermeasures, Volume Sensor" has begun studies towards a multicriteria fire detection system that incorporates optical, acoustic, pressure, and electronic nose sensors.

Integrating sensor information beyond the individual sensor to a global or neighborhood approach will broaden the information available to allocate resources and fight fires more effectively. Preliminary studies with a multivariate statistical processing algorithm to monitor a network of sensor arrays have been successful. (JiJi, 2002). The method uses the sensor location and temporal data to identify events, determine source location and monitor fire rate of growth. Hotelling's statistic and the *Q*-statistic are employed initially for event detection. Subsequently, contribution plots are used to determine source location, rate of growth and to discriminate between actual fires and their byproducts in adjacent compartments. Multivariate statistical process control is shown to be an efficient method for continuous monitoring of the EWFD systems.

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FIRE SUPPRESSION

Anthony Hamins[1]

Abstract

This paper briefly reviews the history, design limitations and research needs of automatic suppression systems. Over the last 35 years there have been great advances in our understanding of the mechanisms of fire suppression. There are, however, still huge gaps in our ability to predict suppressant requirements and design effective inexpensive suppression systems.

In the future, innovations in suppression systems could involve a combination of early fault-free detection, a directed response matching the quantity of the agent precisely to the requirements of the fire, and reduced negative side effects such as water damage, environmental insult, and agent toxicity. These resolutions lend themselves to smart suppression based on scenario-specific engineering analysis.

To provide a foundation for the future, research is needed on the complicated multi-phase processes by which a condensed phase agent extinguishes a fire. In addition, further understanding of chemical mechanisms associated with halon replacements is needed to provide a scientific basis for improved suppressant system design. As an example of a novel approach to fire suppression, a description of solid propellant gas generators is provided. These promising devices illustrate the need to support the development of new suppression technologies.

Introduction

During the last 35 years, there have been great advances in the understanding of the mechanisms of fire suppression. During this period, there have been numerous conference proceedings dedicated to fire suppression research and many articles reviewing the status of suppression research and suggesting future directions (Fristrom 1967; Heskestad 1980; Emmons 1986; Friedman 1986; Gann 1991; Yao 1997; Grosshandler 1998; Grant 2000). There are, however, still huge gaps in our ability to predict suppressant requirements, and design effective inexpensive suppression systems.

The world of fire suppression applications is extremely broad. It is composed of several communities. The first is automatic fire suppression systems. This community is represented by two distinct camps: the water sprinkler industry, which protects occupied building spaces, and the camp involved with protecting unoccupied or easily evacuated spaces. The latter camp uses halocarbons, carbon dioxide, or similar systems to protect buildings and structures (e.g., trains, boats, aircraft, motor vehicles). A second distinct fire suppression community deals with forest and wildland fires including the protection of buildings at the urban-wildland interface. For this community, a completely different scale of effort is required with potentially huge ecological consequences. A third community is the fire service with more than two million members located in every city and town in the U.S. The Fire Service overlaps with the first two communities, as its members handle every type of fire activity. The diverse applications associated with each of these communities exemplify the complexity of the suppression problem.

Fires addressed by each of these communities are turbulent by nature, which complicates the understanding of the physics of suppression. Much progress, however, has been made through the examination of simple laminar flames. This is true of the theory of gas-phase flame extinction, which significantly advanced the understanding of

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the mechanisms of flame extinction. The ratio of the characteristic residence time of a parcel of fluid in a flame to the characteristic chemical reaction time is known as the Damköhler number (Da), which reflects the flow-chemistry interaction. Liñan (1974) used asymptotic analysis to analyze the extinction of laminar diffusion flames and showed that as Da decreases, the maximum flame temperature decreases until a critical value of the Da is obtained when the flame abruptly extinguishes. The Damköhler number criterion suggests a number of strategies for extinguishing fires, that include increasing the flow field strain rate, cooling the reactants, reactant removal, separation, or chemical inhibition (Williams, 1981). The elegance of the theory is its applicability to fire suppression phenomena addressed by each of the fire communities, involving advanced suppressant designs such as a solid propellant gas generator or just plain water, forest fire fuels or jet fuel.

This paper addresses some limitations in the design of current fire suppression systems, suggested research needs and barriers hindering research advances. The paper is broken into several parts. The first deals with the history, design limitations and research needs of automatic water sprinklers. The second section discusses halon replacements and the need for further understanding of chemical mechanisms. The third section discusses features of a specific halon alternative, the solid propellant gas generator, which represents a novel approach to fire suppression. The fourth section discusses barriers that are inherent limitations to progress in suppression research. Each section makes suggested research recommendations.

Water Sprinklers

Any structure that does not have an automatic sprinkler system is vulnerable to the effects of fire as manual fire fighting is often limited in its ability to control a fire. One of the great technological innovations associated with fire protection is the water sprinkler, which has prevented the loss of a tremendous amount of lives and property (Rohr 2000). Major A. Stewart Harrison of the First Engineer London Volunteers was the inventor of the first modern automatic sprinkler (Fig. 1) in 1864 (Woodbury 1892). The sprinklers were to be hung pendant style from water pipes on the ceiling. The modern fire sprinkler would have had a very different history if it weren't for systematic research on the behavior of materials.

By 1670, Isaac Newton's interest in alchemy led him to perform many experiments in inorganic chemistry (Christianson 1984). This interest influenced his scientific achievements including crafting a high quality mirror for the first reflecting telescope and the invention of solder, which he created in 1699. As Master of the Mint in London, Newton discovered that the alloys of Bismuth, Lead, Cadmium and Tin had significantly lower melting temperatures than the pure metals themselves (Woodbury 1892). These materials found many new applications over the next hundred years and when Harrison created the water sprinkler, the fusible solder link played a critical role. Are parallel breakthroughs possible today that would facilitate effective fire suppression?

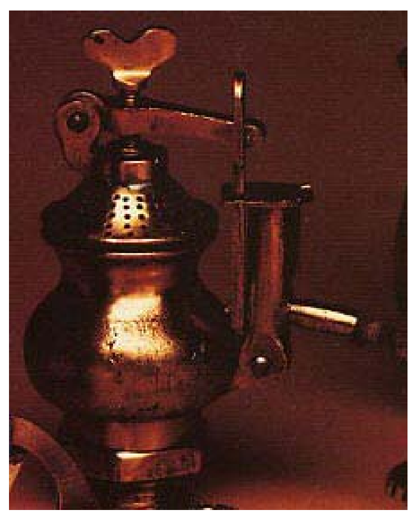

Figure 1. Perforated sprinkler head with a fusible solder link.

Historically, water has been the most common medium used for suppressing fires. Some have suggested that nature could not have designed a better suppressant. It is relatively inexpensive, non-toxic, environmentally friendly, chemically stable, compatible with many materials, pumpable, and typically available in large quantities.

Residential fire sprinklers are fairly effective. In an analysis of fires in homes, NFPA estimates that the current generation of water sprinklers reduce the chance of death by 73% (Rohr 2000). But few residences (1% to 2%) have sprinkler systems. The barrier to improved fire safety in this instance appears to be cost and of course politics. If the current generation of sprinklers will not penetrate the residential market, is it possible to develop an effective and less-expensive suppression system?

Although sprinklers are generally effective, there are some special problems and gaps in performance associated with water sprinklers under particular situations (Rohr 2000). This includes, for example, fires that initiate in proximity to a person or in a concealed space. Fast spreading fires can “overpower” a fire sprinkler system. Smoldering can be deadly for an immobile person in its vicinity. Water is expensive if it has to be handled and stored in large quantities for emergency purposes, for instance in rural areas.

There is a level of crudeness used in the design and approval of automatic water sprinklers. Currently, sprinklers are designed by empiricism, by filing metal and banging with a hammer until the water (with and without a fire present) appears well distributed at a particular plane below the sprinkler head. Because sprinklers are not directed towards the fire, water is often over-applied. There are environmental problems associated with over-use of water in suppression activities. An extreme example is the 1986 Swiss case when approximately 20,000 m^3 of extinguishing water containing pesticides and mercury ran into the Rhine River, runoff from a chemical warehouse fire (Holemann 1994). Although there has been an evolution in sprinkler design, the original strategy remains essentially unchanged since its origins.

To provide a foundation for the future, research is needed on several fronts including the complicated multi-phase processes by which a condensed phase agent extinguishes a fire. This includes the droplet/spray interaction with the gas-phase flames and the burning fuel. Future innovation in suppression system design could involve a combination of early fault-free detection and directed suppressant deployment, which matches the quantity of the agent more precisely to the requirements of the fire with reduced negative side effects such as water damage, environmental insult, and agent toxicity. These resolutions lend themselves to smart suppression based on scenario-specific engineering analysis.

During the last 20 years, the laser diagnostics needed to address some of these issues has become commercially available. Particle imaging velocimetry (PIV) is a non-intrusive field measuring technique that has been used to characterize the velocity field in a planar field of droplets as large as 1 m x 1 m. Water (or agent) droplets scatter light from imposed light sheets. The spatial displacement of the drops corresponding to two images separated by a known time period is measured and the velocity deduced. Phase Doppler interferometry (PDI) can provide point measurements of droplet size, velocity distribution, and number density. Other laser based techniques are available or under development for characterizing droplet sprays. A number of studies have used these diagnostics to begin to examine water distribution patterns from sprinklers (Sheppard

2001). Some preliminary work has looked at the flow of droplets past obstacles (Presser 2001). Yet, details of the flows associated with the interaction of evaporating drops with a fire or an isothermal plume have not been characterized, nor the large-scale flow structures associated with the momentum of a sprinkler spray. Whereas an improved understanding of the processes of suppressant transport, distribution, and interaction with obstacles is important, so too is the interaction of a suppressant with a burning surface.

Magee and Reitz (1986) report on the water spray suppression of burning thermoplastics with radiant heating. To extinguish the burning PMMA slabs, a critical amount of water must be applied such that the burning rate is reduced to 4 g/m^2-s. Similar results were found for other thermoplastics, except at low water application rates when the burning rate of PE and PS was found to increase as the water droplets penetrated the molten plastic surface and then vaporized, causing molten fuel to be thrown into the gas phase. What is the ideal drop character needed to extinguish a burning material?

Although the interaction of a liquid drop with a surface has been studied for more than 100 years, the complicated fluid mechanic processes associated with liquid droplet/surface interactions are not yet well understood (Manzello 2001). Some studies have shown that the impact energy, surface temperature and surface roughness controls drop behavior and its tendency to spread, splash, or rebound. To address suppression of burning materials, the complex heat transfer processes associated with droplet/surface interactions need to be better characterized.

A better understanding of agent mass and heat transfer processes would provide a scientific basis for the creation of rational engineering tools and improved suppressant system design. The exact form of the ultimate suppression system is not clear, but it might integrate detection and a smart nozzle with water additives, water mist, or alternative agents.

Halon Replacements

The world-wide effort over the last decade to find a suitable replacement or alternative for Halon 1301 for use in unoccupied spaces has not identified a gold star replacement, but many advances in the understanding of fire suppression have been made. The development of a number of advanced agent systems, screening methods, and knowledge about the physics of flame suppression has been developed. In particular, work sorting out the chemical and physical behavior of fire suppressants is noteworthy (Sheinson 1989; Ewing 1994).

An intriguing summary of 40 years of flame inhibition experiments in premixed flame systems is shown in Figure 2 (Babushok 2000). Here, the additive effectiveness is defined as the relative agent concentration required to diminish flame speed by 10% as compared to Halon. There is almost a three order of magnitude difference between the most effective metallic compounds and the least effective inert compounds. The grouping together of agents that contain a specific element implies that inhibition is caused by a specific atom, relatively independent of the ligands associated with the agent molecule. Linteris (2002a) has investigated the super metallic agents in Fig. 2 and shown that while the metal compounds can be very effective in premixed flames, their marginal effectiveness decreases rapidly above a volume fraction of a few parts per million and their effectiveness in (coflowing nonpremixed) cup burner flames (NFPA 2001) is much less than expected. Through a series of light scattering experiments, Linteris postulates that some metallic compounds involving Fe and Mn condense to form particulates in the coflowing diffusion flames, which then do not participate in flame inhibition in an effective manner. This is in contrast to Na and K containing compounds, which when introduced into cup burner flames as solid powders are very effective, even more than CF_3Br on a mass basis (Hamins 1996). Linteris (2002b) concludes that the regions of cup burner flames, which are most sensitive to chemical inhibition should be investigated to better understand the mechanisms of flame suppression. Further information on the detailed chemical kinetic mechanisms involving compounds containing Br, I, P,Mn, Sn, Si, Ge, As, Sb, Ti, Sn, Cu, Cr, and Pb (Tapscott 2001) would promote the accuracy of such models. These recent studies demonstrate that fundamental investigation of suppression kinetics is a rich field, deserving further attention. The design of more effective suppressants may be possible through improved understanding of the kinetic mechanisms of fire suppression coupled with bench-scale experimentation.

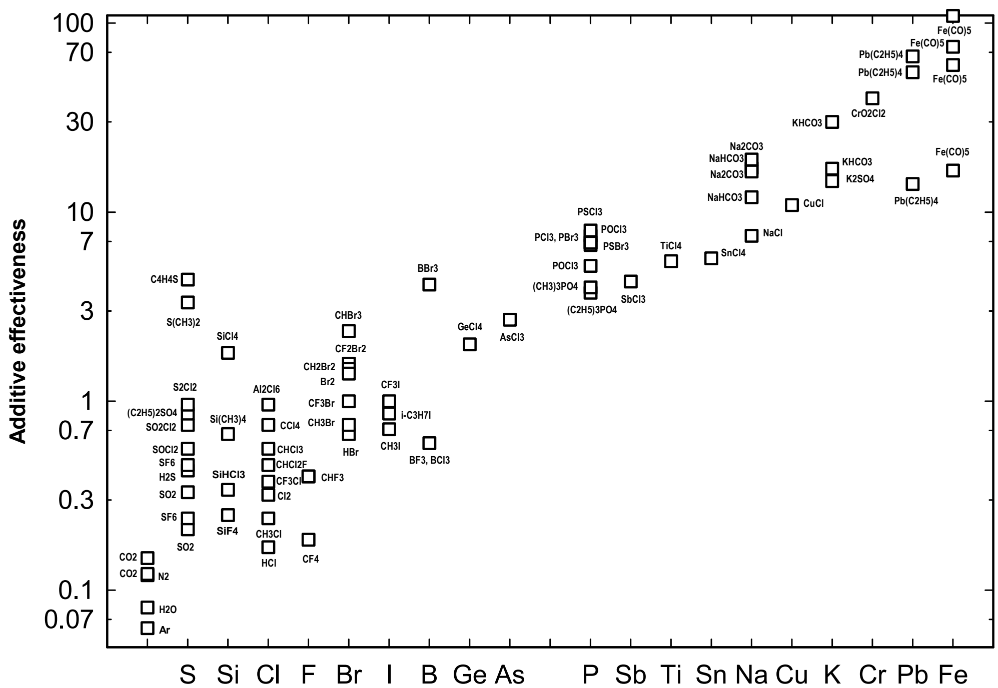

Figure 2. The relative additive effectiveness for various agents.

Solid Propellant Gas Generators

In the search for a suitable halon alternative, novel types of extinguishing agents and delivery mechanisms have been developed. One class of such devices is the solid propellant gas generator (SPGG). Through solid-phase combustion, the device rapidly yields hot exhaust products (principally gaseous N_2, CO_2, H_2O vapor, and potassium salt particulates) that can be used as fire suppressants. A number of experiments were undertaken to examine the effectiveness of SPGG in full-scale and laboratory-scale configurations.

Figure 3. Dripping and pooling underbody gasoline fire suppressed by SPGG.

Vehicle Fire Suppression

Vehicle fires represent approximately one-quarter of the total number of fires responded to by local fire services (U.S. Fire Administration 1997). Although fires represent only a small percentage of vehicle related injuries, they account for a significant percentage of fire injuries. In 1994, of the 15,000 fire-related injuries in the U.S., approximately 10 % were vehicle related (U.S Fire Administration 1997). For the years from 1989 to 1993, there was an average 425,000 fires in vehicles per year (Stewart 1996). A large proportion of fires occur after rear-end collisions, likely related to fuel system leaks and underbody fuel-fed fires (Tessmer 1994). Depending on the fire scenario, conditions in the passenger compartment can become untenable after several minutes. Post-collision fires are particularly dangerous because evacuation of the vehicle is often impossible (e.g., broken bones, jammed doors).

There are many parameters that might affect the suppressant distribution and effectiveness in a vehicle fire including the nozzle type, number, placement, orientation, reservoir size, and pressurization. In addition, ambient effects (wind), geometric effects (flow field obstacles; enclosure openings), fuel effects (fuel type, location, flow rate) and the flow field velocity (as influenced by vehicle movement or operation of the engine fan) may play a role. The intricacy of these real-scale effects is difficult to appreciate until observed through experimentation.

It is conceptually possible to successfully suppress almost any fire, if enough of a suitable suppressant is utilized. In practice, however, penalties such as system mass, volume, and cost will limit the fire scenarios that can be addressed. The experimental results showed that it is highly improbable that a practical on-board fire suppression system will be able to extinguish all possible engine compartment and underbody fires (Hamins 2000). Full-scale underbody suppression experiments (see Fig. 3) showed that suppression of a (333 mL volume) gasoline dripping pool fire was achievable when the fuel was located under the vehicle footprint for low wind conditions. The SPGG was effective under conditions of low to moderate winds, even for fires burning approximately 1 m beyond the footprint of a vehicle, when the fuel puddle was not behind a tire. The rapid agent delivery provided by these unique devices proved advantageous for the transport of agent past obstacles in the flow field.

Aircraft Engine Nacelle Fire Suppression

A series of suppression experiments investigated the relative effectiveness of halogenated agents and solid propellant gas generators (SPGG) in suppressing a series of spray fires with and without a fuel re-ignition source (Hamins 2002). Figure 4 shows a schematic diagram of the test facility. Several agents were tested including CF_3Br, C_2HF_5, and two basic types of SPGG, including one that produced inert gases in conjunction with a fine solid particulate composed of K_2CO_3 and one that produced inert gases only. The effectiveness of the SPGG was dependent on its composition and delivery rate. The SPGG effluent, which contained a significant percentage of K_2CO_3 particulate was particularly effective for re-ignition protection, a scenario which dominates agent mass requirements for the halogenated agents.

SPGG is currently operational on-board the V-22 aircraft. The success of the SPGG in the V-22 and the F-22 test programs exemplifies the importance of supporting novel approaches to fire suppression. The support of new advanced agents should continue as novel design ideas address fire scenarios that pose a significant publics safety concern.

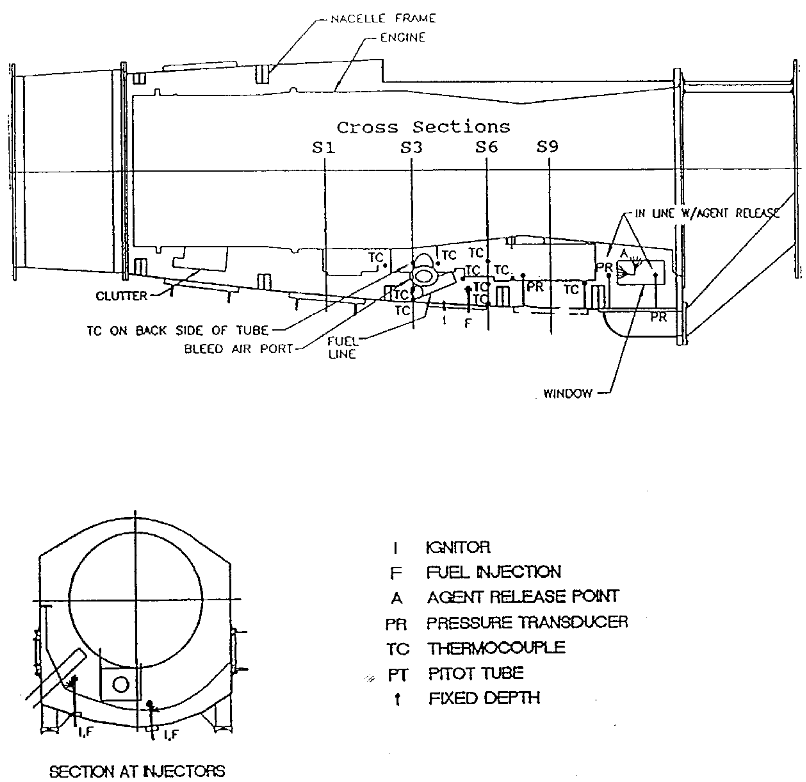

Figure 4. Cross-sectional view of the simulated F-22 engine nacelle fire suppression test facility.

Barriers to Change

There has been remarkably little overlap between researchers in the various fire communities; those involved with automatic protection of occupied and unoccupied spaces, the Fire Service, and those in the forest fire community interested in building fire protection. There may be even less interaction between a different pair of communities - those researchers involved in bench-scale suppression research and those involved in full-scale suppression testing. Lab-scale experiments benefit from better control of conditions, yet the issues of scale-up are not trivial as some important phenomena in full-scale may have been over-looked in the design of a reduced–scale experiment. The potential for cooperation among these various communities appears to be large. After all, the essential physics of suppression is scenario independent. The exchange of research insight beyond these barriers, from one community to another, could be supported by encouraging grant proposals by teams of researchers from different research communities. For example, overcoming cost as a barrier to change might best be addressed by a team composed of researchers from industry with those from academia.

Conclusions

In a time frame of one hundred years, it is possible to imagine an array of high density nano-sensors that trigger early fault-free fire detection, an array of suppressant release nozzles that facilitate directed suppression that matches the quantity and location of the agent precisely to the requirements of the fire with reduced negative side effects such as water damage, environmental insult, and agent toxicity. Today, issues of cost shatter this fantasy, but in the future that may not necessarily be the case. Innovations in suppression will likely come about from a combination of research on transport processes, advanced agent kinetics, innovation in engineering design and serendipity. These resolutions lend themselves to smart suppression based on scenario-specific engineering analysis.

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FIRE SIGNATURES AND DETECTION

D. T. Gottuk[1]

ABSTRACT

Fire detection systems are used for both life safety and property protection and have saved thousands of lives in the United States. Despite its wide spread use in residential to industrial applications, there is still much that can be improved, leading to increased life safety and the reduction of property loss. Continued research is needed in the area of multi-signature detection, particularly gas and smoke combinations which hold the greatest promise for improved performance compared to smoke detectors alone. This research includes the identification of low concentrations of chemical species from fire and nuisance alarm sources. Achieving the goal of detailed signature identification will require the development of new sensor technologies (e.g., electronic nose sensors). The development of low cost gas sensors, particularly CO and CO_2, that are stable with a functional life of ten years or more is needed to produce marketable multi-signature detectors. The development of multi-signature detection will also benefit from advancements in multivariate analysis techniques that allow more efficient development and testing of fire alarm algorithms. Lastly, a coordinated effort is needed between modelers, experimentalists and manufacturers in developing detector performance metrics and accurate models for the calculation of detector responses under realistic installation conditions.

Fire Detection

Fire detection is an integral part of fire safety in the United States. Fire detection is used for life safety (evacuation), property protection and for automatic suppression activation in a wide range of applications from residential housing to aircraft hangars. The early notification of occupants to a fire is a key component to the life safety features of a structure. This early notification is dependent on several factors: 1) sensing a signature of a fire prior to life threatening conditions, 2) determining that the signature represents a fire and not a nuisance source, and 3) distributing an alarm notification signal to the occupants.

Fire signatures can be defined as any fire product that produces a change in the environment, such as electromagnetic radiation (e.g., light), heat, acoustic energy or particular gases. A common signature used for fire detection is smoke, the condensed phase component of products of combustion from a fire. Even this fire signature

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represents a range of conditions. The character of smoke is dependent on the type of fuel burning, the mode of burning (smoldering or flaming) and the environmental conditions. Smoke can consist of distributions of many small particles, few larger diameter particles, spherically shaped aerosols or irregularly shaped agglomerates (Mulholland, 1995).

Although fire detection has played a significant role in improving fire safety in the U.S. (Hall, 2000), there is a recognized need for improvement. A main objective is to increase detection sensitivity and increase the reliability of the detection system through improved nuisance alarm immunity. Improved reliability is needed such that fire detection systems can automatically control fire suppression systems. For example, in the past nuisance alarms have caused expensive releases of fire suppression systems in aircraft hangars. The U.S. Airforce deemed the problem serious enough to prohibit the use of automatic detector-controlled suppression systems. The use of only manually controlled suppression implies that a higher risk of property damage was accepted given the potentially increased time to respond.

In addition to increased reliability for property protection, reduced nuisance alarms would translate into more lives saved, particularly in residential occupancies. Given that 73 percent of civilian fire deaths and 71 percent of civilian fire injuries occur in residential fires [FEMA, 2001], improvements in residential fire alarm equipment has the potential for the greatest impact of improving life safety against fire in the U.S. A Consumer Product Safety Commission study found that approximately 30% of fires in the United States occurred in instances where smoke detectors were either nonexistent or inoperable (Smith, 1994). The CPSC research found that nuisance (false) alarm sources caused many people to remove, disable, or otherwise alter their smoke detection equipment, thus defeating its very purpose as a life-saving device. Therefore, improving nuisance alarm immunity should be a key objective for new fire detection technologies. Though limited research is focusing on nuisance alarm immunity, the development of new devices and test methods to provide better immunity and to recognize the benefits has not really materialized in the industry (FPRF, 2002). Addressing the nuisance alarm problem needs to be a priority. As further evidence, a National Fire Protection Association (NFPA) survey showed that 69 percent of the public assumes "no fire" and only 7 percent assume "fire; leave now" when a smoke alarm sounds (Hall, 2000). This poor response is attributed greatly to peoples experience with nuisance alarms.

Particularly over the past decade, improvements in detection have been enabled by cheaper and more sophisticated computational processing (Gottuk, 1998). These advancements have also led to research and development of multi-criteria detection systems. These systems generally have two main components: the combination of sensors and advanced processing schemes for using the sensor output. In the broadest definition of the term, multi-criteria detection can consist of processing the output from a single sensor to yield multiple parameters (e.g., absolute value, rate of rise or fluctuation). For example, Pfister (1983) reports on work in which better discrimination between smoke and water vapor is achieved with an ionization smoke chamber (the most common type of residential smoke alarm) by comparing ion current output at both low and high voltages. By measuring multiple outputs from a single sensor, better discrimination between a real fire (smoke) and nuisance alarm (water) source can be achieved. To the author's knowledge, this technology is not being used in commercial devices. The vast majority of research work in the area of multi-criteria fire detection has focused on processing data from multiple sensors (i.e., multi-signature detection).

The most common type of fire warning equipment are smoke detectors, which are found in residential to industrial applications and encompass multiple smoke sensor technologies. Other than smoke detectors, the most common detection technologies are heat detectors and optical fire detectors (flame detectors).

Currently there are primarily two types of smoke detectors, ionization and photoelectric (Gottuk, 1998; Bukowski, 1994). These detector types respond differently to different smoke properties. For example, ionization smoke detectors generally respond faster to flaming fires than smoldering fires because flaming fires have a larger number of particles. Photoelectric smoke detectors generally respond faster to smoldering fires than flaming because the smoke is characterized by larger particle sizes. The two detection technologies illustrate the diversity of smoke measurements. Although some may consider smoke a single signature, there are multiple parameters that can be used to characterize it. These parameters include the particle size distribution, the number density, mass and optical properties. These parameters are dependent on the type of fuel burning, the mode of burning (smoldering or flaming), the environmental conditions and the time during smoke transport, during which particles can agglomerate. Smoke detection technologies have changed little over the past 20 years in part because of a lack of knowledge regarding the character of smoke from fire and nuisance sources. A quantified characterization of smoke properties for a range of applicable sources would provide the basis for improvements or the development of new smoke measurement technologies. The majority of fire detection testing performed has not included measurements of smoke properties, such as particle number density and size distribution, because of the difficulty of making these measurements. The development of reasonably priced experimental techniques for making in situ transient smoke property measurements is needed.

Heat detectors respond to temperature changes in the surrounding gas. A fixed temperature heat detector will signal an alarm when the active element of the detector reaches the designed alarm temperature. Depending on the application, activation temperatures may range from approximately 38 C (100 F) to 302 C (575 F) (Bukowski, 1994)). Other types of heat detectors include rate compensated and rate-of-rise. Heat detectors are not considered early warning detection devices since a reasonable size fire is required to achieve the alarm threshold [Bukowski, 1976]. The use of temperature measurements as part of a multi-signature fire detector is discussed below.

Optical fire detectors measure the radiant energy from a fire. These detectors utilize both single sensor and multi-sensor technologies, which detect light in the ultraviolet (UV), visible and/or infrared (IR) spectrum. The most common types in use today are UV/IR, dual IR, and triple IR devices. The majority of units are UV/IR, but newer triple IR technologies have been gaining wide spread use. In a Navy research program, triple IR detectors provided the best detection response to fuel spill fires and the very good nuisance alarm immunity compared to the other optical fire detectors (Gottuk, 2000). One manufacturer has a device that detects in the UV, visible and IR. These combined sensor units are multi-criteria detectors. Besides detecting energy at multiple wavelengths, the IR detectors also evaluate the fluctuations (frequency) of the incoming energy which correspond to the pulsations of a fire plume. Both the combination of sensors and the use of energy pulsation frequency have contributed greatly to developing more nuisance alarm resistant fire detectors.

Optical detectors can provide very fast response to flaming fires depending on the distance from the fire, the line of sight, and the particular detector technology. Optical detectors are not well suited for smoldering fires or in applications where the field-of-view of the detector may be obscured. The high cost of this technology and its particular applicability to wide open spaces and flaming fires does not make optical fire detection suitable to many applications, such as residential housing and office buildings.

Due to the relative magnitude of residential fire deaths and injuries, improving detection for residential applications should be an area of increased research. Advances made for the residential applications would translate to a broad range of applications where smoke detection is currently used. Generally, the use of smoke detection is in applications primarily focused on fire detection for life safety. Optical fire detection and heat detection are associated with property protection more so than smoke detectors.

Multi-Signature Fire Detection

The use of multiple signatures for fire detection is an active area of research (Gottuk, 1998; AUBE, 2001). The concept of multi-signature detection is a logical progression in the advancement of automatic fire detection. In many aspects, a person represents the best fire detector because of his/her ability to detect a wide range of fire signatures. A person's senses allow for the detection of sound, heat, light, smoke and odors (gases) from a fire. In addition to being able to detect multiple signatures, the person has a high level processing capability to input and analyze these signatures to yield very good discrimination of real fire and nuisance events. Ultimately, the science of fire detection is an effort to mimic man. The two main areas of research have been to identify useful fire signatures and to develop the advanced processing for accurate nuisance/fire source discrimination and alarm. A review of the state of the art is provided in Gottuk (1998).

Multi-signature fire detection technologies continue to offer the most promising means to achieve both improved sensitivity to real fires and reduced susceptibility to nuisance alarms (Conforti, 1999; Gottuk, 1998; Meacham, 1994; Fischer, 1994; Hagen, 2000). Based on the work to date, the use of gas sensors in combination with smoke sensors holds the greatest potential for successful multi-criteria detectors. Temperature sensors are used in a number of commercially available combination detectors (primarily photoelectric smoke and heat), but most experimental data shows little to no improvement in fire detection capabilities with the addition of the temperature sensor (Wakelin, 1997; Gottuk, Hill et al. 1999, Rose-Pehrsson 2000).

Most research with gas signatures has focused on the utilization of species that are prominent products of combustion, such as carbon monoxide (CO) and carbon dioxide (CO_2), and to a lesser extent oxygen and general hydrocarbons. These species have been used because they are key products of combustion and are easily measured in the lab with standard measuring techniques, i.e., bench-top equipment. It is important to note that not until about the last 10 years were CO or CO_2 sensors available that had the potential to be incorporated into typical detector heads. The most promising CO sensors are electrochemical cells, and the most promising CO_2 units have been NDIR sensors. Costs for both sensor types has been decreasing considerably over the past decade, making the use of these sensors a more practical consideration. However, more work is needed in the manufacture of cheaper sensors with better performance specifications. For example, low cost CO electrochemical cell sensors with part-per-million (ppm) concentration resolution and a ten year life are desirable. Carbon dioxide sensors are still rather costly relative to the price of smoke sensors. The scarce availability of cost effective gas sensors with stable operation and long life has been a deterrent for manufacturers to developing multi-signature detectors.

There are several advantages to developing a combined CO/smoke detector. One of the primary advantages is the ability of a combined sensor algorithm to produce faster alarms to fires while reducing many nuisance alarms (Gottuk, 1999). Most nuisance alarms which are not related to hardware problems are the result of non-fire aerosols. Cooking aerosols, dusts, tobacco, and aerosol can discharges are examples of sources which cause nuisance alarms (Breen, 1985). Cooking aerosols and steam (e.g., from a shower) are the most common nuisance alarm sources (Smith, 1994; Kuklinski, 1996). Of these examples, only tobacco smoke and possibly gas fired cooking are expected to contain carbon monoxide. This makes carbon monoxide an attractive fire signature for detection purposes. The fact that carbon monoxide is the causative agent in a majority of fire deaths further enhances the desirability of using CO as a fire signature. Given the toxic properties of CO, a combination CO/smoke fire detector can also serve as a CO alarm for exposure safety. Currently, there are no combination gas/smoke detectors on the market. However, several manufacturers have or are still working on developing units. In some cases, the manufacturers have put the development programs on hold for both marketing and technical reasons. One of the impediments has been the availability of cost-effective gas sensors that are stable with a functional life of ten years or more.

Detection of Low Concentrations of Chemical Species

Several studies have investigated the use of hydrocarbon sensors (typically metal-oxide type) and oxygen measurements, but the inclusion of these signatures in a multi-signature detector has not been demonstrated to yield a marked improvement over standard smoke detectors. Only a few studies have investigated the use of a wide variety of gas species (e.g., Chen, 2000; Gottuk, Hill et al., 1999). Chen et al. used a FTIR analyzer and measured CO, CO_2, H_2O, CH_4, CH_3OH, Formaldehyde, HCl, C_2H_4, N_2O, NH_3, CF_4, NO, methyl methacrylate, IPA, C_2H_6, C_3H_6, C_6H_{14}, C_2H_2, and C_6H_6. The resolution of these measurements was on the order of ppm. However, for many of the fire and nuisance sources, species concentrations were below the detectable levels. Gottuk et al. measured CO, CO_2, O_2, H_2, C_1-C_6 hydrocarbons, HCL, HCN, H_2S, SO_2, NO, NO_2, relative humidity and smoke. The majority of the gas species were measured using electrochemical cells with ranges from 5 to 200 ppm. Species such as HCL, HCN, H_2S, SO_2, NO, NO_2 had measured values of only fractions of a ppm for many fire and nuisance sources. Because of the small or non-existent values measured for the fire and nuisance sources, some of the species were not useful for an alarm algorithm. The results indicated that the more primary products of combustion (CO2 and CO) and smoke were the key signatures. Both of these experimental studies indicate that the use of many gaseous signatures is hampered in part by the inability to measure low levels, on the order of parts per billion.

As illustrated with our sense of smell, a fire can be detected and even classified using the nose (a multi-signature sensor) which can detect gases at much lower concentrations than can be feasibly measured by a potential fire detector sensor. The development of an electronic nose (a multi-sensor array) for fire detection purposes is an area of research that warrants more attention. Particularly, work is needed in developing low cost, compact sensors that can measure a wide range of chemical species at low concentrations. In addition, there is also much work needed in the development of the data processing that will accompany the sensor development. This data processing will most likely entail much experimental testing to be able to interpret the outputs of the multi-sensor arrays.

The development of a fire alarm algorithm for an electronic nose can be accomplished in one of two ways. One, establish a database of specific individual gas species (and other signatures) from fire and nuisance source events using general measurement equipment. Then develop a multi-sensor array that can be used to provide outputs specifically correlated to the measured species in the database. This approach provides a means for wider use of data in the development of alarm algorithms. That is, one set of tests (database) can be used for multiple sensor arrays. However, many multi-sensor array technologies may not provide species-specific concentrations that match the database. This leads to the second method.

A sensor array is developed and is exposed to fire and nuisance sources to develop a database of sensor outputs (fingerprints) for the different events. This method requires an extensive set of tests for each sensor array developed. Tests may even need to be repeated for any significant design change that alters the output characteristics of the sensor array. Though there is significant research in the area of electronic nose technology, little has focused on fire detection. Because of the complexities of being able to accurately discriminate between fires and nuisance events, a concentrated effort is needed in both the development of sensor arrays with alarm algorithms and establishing a quantitative understanding of the low level concentrations (< 1 ppm) of chemical species characteristic of both fire and nuisance sources.

Nuisance sources

In general for any combination of sensors in a fire detector, the key is to have a good understanding of the signature patterns from fire events and to know how to discriminate between these fire signatures and those from nuisance sources. This problem becomes quite difficult for nuisance sources, such as controlled combustion events, that have similar characteristics to fires. Examples include occasional smoke from fireplaces, use of acetylene torches, and burning food in a kitchen. The problem is compounded by cases in which a nuisance source, such as slightly burning toast, transitions into an actual fire, i.e., the toast chars and starts to flame in a malfunctioning toaster. The key question is how to make the judgment call as to when the situation becomes a potential fire threat and not just a nuisance event if an alarm occurs. This judgement is often difficult for a person; now an alarm threshold must be established based on limited sensor data. Besides these difficulties, the science of characterizing nuisance sources (those actually causing smoke alarms to respond) has been very limited and warrants more attention. As new multi-signature detectors are developed to provide better nuisance alarm immunity, test standards (e.g., UL 217 and UL 268) need to be improved to evaluate the detectors for these features in order to recognize the benefits (FPRF, 2002). Without a means to quantify and document improvements in nuisance alarm immunity, manufacturers have difficulty convincing consumers to pay higher prices for detectors with supposedly improved performance.

Development of Alarm Algorithms

As more signatures are identified, the development of high level processing becomes even more important. The development of fire algorithms has been an area of research as evidenced in the literature, but the amount of work has been limited and much has been outside of the U.S. (AUBE '99 and AUBE '01). The research areas of artificial intelligence, the use of neural networks and fuzzy logic algorithms, is playing an important role. Much of the fire detection research has focused on the development of alarm algorithms using fuzzy logic and neural networks for event classification and discrimination between fire and nuisance sources (McAvoy, 1996; Milke, 1995; Okayama, 1991, Okayama, 1991a; Okayama, 1994; Nakanishi, 1995; Rose-Phersson, 2000, Wang, 2001). Current work by the U.S. Navy has employed probabilistic neural networks (PNN) developed for non-fire applications and applied them successfully to fire detection (Rose-Pehrsson, 2000, Rose-Pehrsson, 2002 and Gottuk, 2001). Using a PNN with a four sensor combination (ion, photo, CO and CO2), a prototype fire alarm system was demonstrated to provide overall improved performance compared to conventional smoke detectors (generally faster response to fires and better nuisance source immunity).

The success of developing these alarm algorithms can require substantial testing. Particularly for neural networks, which are developed from a database of fire and nuisance signatures, the question arises whether the database is substantially broad enough to yield a robust fire alarm algorithm suitable for the majority of applications. It may be possible to employ different or new multivariate techniques in the development and validation of fire alarm algorithms which would require fewer experimental tests.

Other approaches for developing alarm algorithms have relied on more simplified mathematical correlations based on signature patterns and methods specifically linked to a knowledge of fire dynamics (e.g., Gottuk, 1999, Ishii, 1991; Richards, 1997; and Davis, 2001). As noted previously for the numerically-driven multivariate alarm algorithms, all algorithm development requires the availability of signature data. This results in large databases of information that are proportional to the number of signatures being evaluated. In the case that multiple aspects of signatures are evaluated (i.e., magnitude and rate-of-change), the databases can become quite cumbersome to process, particularly when trying to manually review from a fire dynamics perspective. The development of generic tools, such as data processing software, to aid in the development and validation of alarm algorithms would be helpful.

Perceptions and Education

The education of the public (both consumers and installers) is an area in need of improvement. The first hurdle is the problem that fire alarm systems are installed to meet code not to provide the best life safety protection possible. This is particularly true for many commercial and industrial installations. Manufacturers estimate that about 95 percent or more of the programmable detection systems are never changed from factory default settings. Many of these systems could be optimized to provide better performance by implementing standard features in the system or adjusting alarm sensitivity levels.

Many consumers take fire detection for granted. For instance, smoke alarms[2] in a home are frequently not tested nor maintained. However, these electronic devices are expected to always work. People expect a smoke alarm to be able to save a person from a fire regardless of particular conditions within the residence (e.g., closed doors and relatively long distances between potential fires and the alarm). The National Fire Alarm Code (NFPA 72) provides minimum standards for smoke alarm installations in residential occupancies. Particularly with larger houses, the use of more than the required "one smoke alarm per floor" would be warranted. Unfortunately, many installers (and homeowners) are not aware that more smoke alarms maybe needed, despite this being a recommendation in NFPA 72 and in instruction manuals.

An informal consensus of industry experts and manufacturers is that much of the public is very cost sensitive in implementing fire alarm equipment (i.e., this fits the misconseption that minimum requirements provide all the safety needed). This is a problem for introducing new advanced smoke alarms which may cost more but provide significantly higher levels of safety (faster response time and less nuisance alarms). Both the education of the public as well as the quantification of the level of safety provided are needed to address this problem. Quantifying the level of safety provided requires the development of engineering performance metrics (Cholin, 2002) and standardized test methods (FPRF, 2002).

Detector Response

One means of quantifying the level of safety provided by a detection system is to be able to calculate the response of a smoke detector. With the increasing use of performance-based fire protection design, it is also imperative that predictive tools and methodologies be available to design and analyze fire detection systems (Cholin, 2002, Schifiliti, 2001). Without the technical tools for calculating the response of a fire detector (particularly smoke detectors), performance-based analyses can not fully account for or weigh the benefits of a fire detection system relative to other fire safety systems.

Presently, there are two basic methodologies in use for estimating the response of smoke detectors – the Temperature Rise Method and the Optical Density Method (Schifiliti, 1995; NFPA 72). Unfortunately, neither provides very accurate results. In fact, only recently was the potential accuracy for alarm estimation using the second methodology evaluated (Geiman, 2002). Schifiliti (2001) reports on the problems associated with detector response modeling and suggests several research objectives. One is to further develop, test and verify models that describe smoke entry into a detector sensor from outside the housing. Secondly, further test and refine Newman's model for ionization detector response. In general, a coordinated effort is needed between modelers,

[2] A smoke alarm is a device that has both a smoke sensor and a horn. Smoke alarms are typically used in residential occupancies. A smoke detector is generally only a sensor and is wired to a control panel that typically distributes the alarm notification. Relative to this paper, the terms can be used interchangeably.

experimentalists and manufacturers in developing a consistent approach to creating accurate models that can be applied to general classes of detectors at different alarm sensitivity levels. As discussed by Cholin (2002), the development of performance metrics are also needed to achieve the objectives of developing useful detector response models. Establishing these performance metrics will only be possible with the cooperation of detector manufacturers and testing organizations.

Conclusions

Fire detection systems are used for both life safety and property protection and have saved thousands of lives in the United States. Despite its wide spread use in residential to industrial applications, there is still much that can be improved, leading to increased life safety and the reduction of property loss. Improvements include research objectives, education and training and the development of engineering methodologies.

Continued research is needed in the area of multi-signature detection, particularly gas and smoke combinations which hold the greatest promise for improved performance compared to smoke detectors alone. Multiple studies have demonstrated both faster detector response to fires and better nuisance alarm immunity with multi-signature detection. The research needed includes the identification of low concentrations of chemical species from fire and nuisance alarm sources. Achieving the goal of detailed signature identification will require the development of new sensor technologies (e.g., electronic nose sensors). The development of low cost gas sensors, particularly CO and CO_2, that are stable with a functional life of ten years or more is needed to produce marketable multi-signature detectors. The development of multi-signature detection will also benefit from advancements in multivariate analysis techniques that allow more efficient development and testing of fire alarm algorithms.

The ultimate manufacture and use of advanced multi-signature detectors will depend on further education of the general public, installers and engineers to the benefits of the new detection systems. This education should include a better understanding of current fire alarm systems and the means to optimize them using currently available features. A potential problem is a general attitude that a fire alarm system is just code required equipment not a valued piece of life safety equipment. Improved fire detectors (multi-signature or otherwise) will not be widely accepted unless consumers are willing to pay higher prices for increased life safety. In order to educate and convince consumers and engineers of the value of improved detectors, detector performance metrics and test standards must be developed to document the added benefits. For instance, the improved nuisance alarm immunity of a multi-signature detector needs to be demonstrated and recognized by listing agencies.

Lastly, but potentially the most important, a coordinated effort is needed between modelers, experimentalists and manufacturers in developing detector performance metrics and accurate models for the calculation of detector responses under realistic installation conditions. With the increasing use of performance-based fire protection design, it is imperative that predictive tools and methodologies be available to design and analyze fire detection systems. Without the technical tools for calculating the response of a fire detector (particularly smoke detectors), performance-based analyses can not fully account for the benefits of a fire detection system relative to other fire safety systems.

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PROBABILISTIC METHODS IN FIRE SAFETY ASSESSMENT: POTENTIAL RESEARCH AND DEVELOPMENT NEEDS[1]

N. Siu[2]

ABSTRACT

Probabilistic methods of analysis provide an important means for conveying information regarding analysis uncertainties to fire safety decision makers. A broad range of issues (e.g., the likelihood of challenging accidental fires, the uncertainties in current predictions of fire environments) can be addressed using these methods. Current research and development (R&D) needs regarding the use of these methods include the development of tools and data for quantifying input parameter uncertainties, and the development of methods, tools, and data for quantifying model uncertainties. From a fire safety improvement perspective, it is essential to identify those scenarios that dominate nationwide fire risk, in order to identify potentially effective mitigation approaches as well as to better focus R&D activities..

Introduction

Probabilistic methods of engineering analysis[3] are playing an increasingly important role in fire safety assessment. These methods are designed to quantitatively address the uncertainties inherent in safety analyses. They not only provide a language and tools to support analysts in making clear statements about the limitations in their results, they also provide a means to convey important information to decision makers who wish to assess and use the analysis results.

The term "probabilistic methods" comes from, of course, the choice of using the theory of probability to develop quantitative statements of uncertainty. The basic unit of measure is the conditional probability, denoted by P{X|C}, which quantifies the analysis team's belief[4] that a particular proposition {X} is true, given that a specified condition {C} holds. Typical propositions of interest can be discrete (e.g., N fires of a certain class occur over the course of a year) or continuous (e.g., the temperature at a particular point in space at a particular point in time falls in the range [T,T+dT]) in nature. The conditions of interest reflect both the analysis boundary conditions (which indicate the area of

[1] The views and conclusions in this paper are those of the author and should not be interpreted as necessarily representing the views or official policies, either expressly or implied, of the U.S. Nuclear Regulatory Commission.

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[3] In this paper, "probabilistic methods" are defined as methods of analysis whose results are stated in terms of probabilities (or related quantities, e.g., frequencies). They are distinguished from probabilistic solution methods (e.g., Monte Carlo simulation methods), which can be used to solve deterministic as well as probabilistic problems.

[4] This paper follows the subjective interpretation of probability, as discussed by Apostolakis (1978, 1990) in the context of engineering analyses performed to support decision-making.

applicability of the results) and the evidence (e.g., empirical data) shaping the analysis team's belief. The theory of probability provides the means to develop the conditional probability of compound propositions in a manner consistent with logic and with the available evidence.

Current Level of Understanding

The application of probabilistic methods to fire safety assessment can range from complete scope probabilistic safety assessments (PSAs), which identify potential scenarios, their consequences, and their probabilities, to focused assessments of the uncertainties associated with the prediction of a particular phenomena under tightly specified conditions.

The models used in these assessments can be deterministic or probabilistic in nature. In addition, the solution methods used to solve these models can also be deterministic or probabilistic. Table 1 provides a number of examples illustrating the various combinations of deterministic and probabilistic models and methods.

Table 1. Example combinations of models and solution methods.

		Solution Method	
		Deterministic	Probabilistic
Model	Deterministic	Zone model Finite difference method	Finite, homogeneous gas layer model Monte Carlo transport method
	Probabilistic	Event tree model Minimal cutset upper bound method	Rule-based evacuation model Discrete-event simulation method

Despite the differences across the various combinations shown in Table 1, some broad statements can be made regarding the current understanding of probabilistic methods (in the context of fire safety assessment applications).

First, the development of efficient probabilistic solution methods has been a subject of active research for a number of decades, and will likely continue to be a subject of research even as current computing capabilities allow us to tackle increasingly complex problems using currently available methods. Examples of methods developed over the years include object-oriented, discrete-event simulation for rule-driven systems, and advanced Monte Carlo sampling schemes to support the application of Bayes' Theorem in the statistical estimation of multiple dependent parameters.

Second, research to develop methods for assessing the uncertainties in model predictions is also underway. This research applies to the probabilistic as well as the deterministic models identified in Table 1, because the predictions of probabilistic models, which address "aleatory uncertainties" (also referred to as "random" or "stochastic" uncertainties), are naturally themselves uncertain to some degree. The methods for uncertainty analysis are aimed at quantifying the "epistemic uncertainties" (also referred to as "state-of-knowledge" uncertainties) in the accuracy of the model predictions.[5]

A complete, formal uncertainty analysis for both deterministic and probabilistic models requires: a) an assessment of the uncertainties in the model input parameters, b) the propagation of these uncertainties through the model structure, and c) the estimation of uncertainties associated with the model structure itself. Methods are available to perform the first and second steps in relatively routine applications. On the other hand, considerable development work remains to be done on methods supporting the third step.

Regarding input parameter uncertainties, widely available statistical techniques can be used when large amounts of directly relevant, unambiguous data are available. When the data are sparse, only partially relevant, or even ambiguous, as may be the case for safety assessments of many actual situations, Bayesian techniques (including expert elicitation) can be used, as discussed by Siu and Kelly (1998). The technical issues remaining involve questions concerning the application of these techniques to specific problems, e.g., how to assign probability values to different potential data sets given a set of evidence. There is also a need to develop, where practical, stronger sets of data. This will reduce the need to use the more elaborate estimation techniques mentioned above.

Regarding the propagation of uncertainties, a wide variety of tools and techniques have been developed over the years. As an example, Helton and Davis (2000) provide a summary discussion of a number of sampling-based methods (e.g., direct Monte Carlo, importance sampling, Latin Hypercube sampling) that can be used.

Regarding the estimation of model uncertainties, the current level of understanding is far less mature. In a 1993 workshop discussing the treatment of model uncertainty in risk assessment applications, even the definition of "model uncertainty" was the subject of considerable discussion (see Mosleh et al, 1995). The conceptual frameworks underlying the various definitions suggested addressed such concepts as the probability of a given model being "correct" and the accuracy of the model in predicting the true (but unknown) value of the output variable(s). The workshop discussions also addressed, to a limited extent, the operationalization of the various definitions.

More recent work by Droguett (1999) argues for a Bayesian approach that uses two forms of evidence: evidence from the model (i.e., the model's predictions for the situation of interest), and evidence about the model (i.e., information about the model structure, and information from previous uses of the models, including benchmarking and validation calculations). This approach, which is represented in Figure 1, expands on discussions held in the previously mentioned workshop and is consistent with the philosophy of current PSAs. Droguett also proposes a number of computational methods for applying the approach that may be useful in a number of fire safety assessment applications. Work remains to develop tools for routine practitioner use, and to develop the data needed by these tools (e.g., comparisons of model predictions against

[5] "Aleatory" uncertainties are those uncertainties that are, for the purposes of the analysis, treated as being irreducible. Thus, if repeated trials of an idealized thought experiment (where the conditions are kept constant from trial to trial) will, assuming no measurement error, lead to a distribution of outcomes for the variable, this distribution is a measure of the aleatory uncertainties in the variable. "Epistemic" uncertainties are those that can be reduced with additional knowledge. Uncertainties in a deterministic variable whose true value is unknown are epistemic. Repeated trials of a thought experiment involving the variable will, in principle, result in a single outcome, the true value of the variable.

experimental observations).

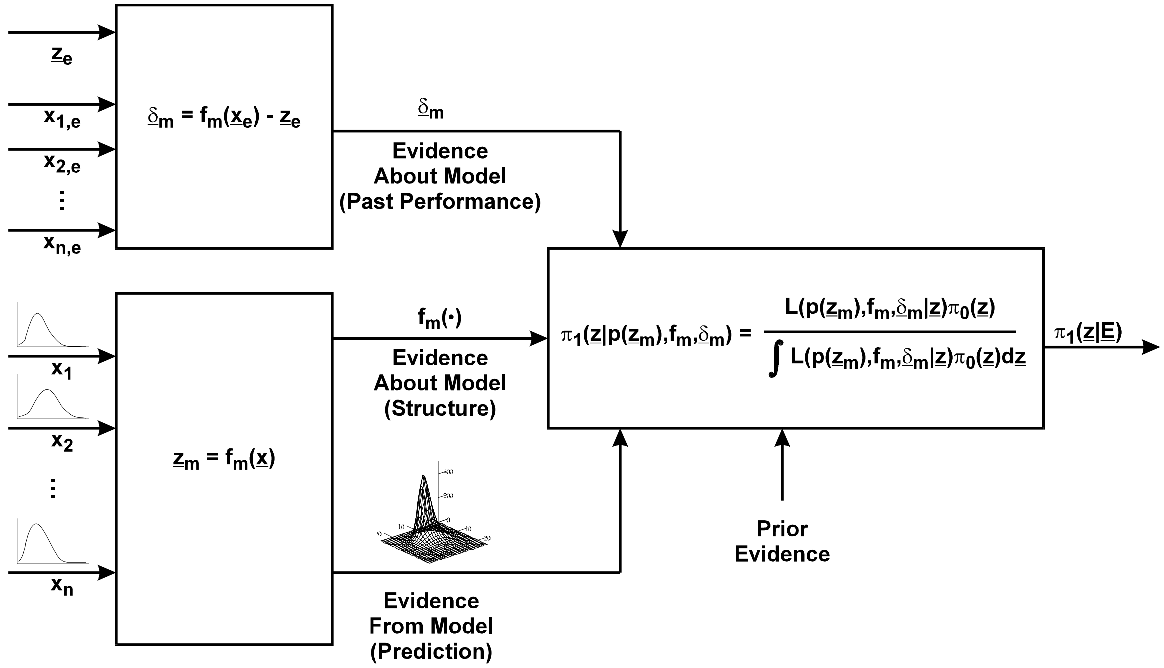

Figure 1. Bayesian Approach to Treating Model Uncertainty

Key Research Needs

From the preceding discussion, it can be seen that improvements could be useful in a number of areas relevant to probabilistic methods. These areas include: the development of efficient numerical methods for solving complex problems (as well as guidance for selecting methods appropriate to the specific problem at hand), the quantification of uncertainty in a set of model parameters when current evidence is weak, and the quantification of uncertainties associated with the structure of a given model.

From a fire safety perspective, however, it may be that improvements in these areas will not have the same benefit as an improvement in a non-methodological area, namely the current state of knowledge regarding the dominant contributors to fire risk.

As indicated by the background notes provided for this workshop, there clearly is a general understanding of the nation's current fire risk (both in terms of life safety and in terms of economics). It is less clear if there is an understanding of the risk-dominant scenarios sufficiently detailed to identify and evaluate potentially effective risk management strategies (which can include R&D aimed at developing improved models, methods, and data for analyses in areas where uncertainties need to be reduced). If a more detailed understanding is needed, then work to reach this understanding may well require a large number of fire safety assessments covering a broad range of building and facility types. It may also require focused R&D activities aimed specifically at developing tools to support the identification of key scenarios. This is not a particularly innovative activity, not is it necessarily a big opportunity for "breakthrough" research. Rather, it is an enabling, and crucial, step in the identification of measures that should lead to real improvements in national fire safety.

Role of Key Institutions

If, as suggested in the preceding section, it is decided that a number of fire safety assessments should be performed to identify key scenarios for all of the buildings and facilities of interest, this could require a substantial investment of resources. Resources would be needed to develop the methods, tools, data, and guidance supporting the performance of consistent analyses, to perform the analyses, to review the analyses, and to implement the results of the analyses. Key institutional support would likely be needed in this major undertaking to develop stakeholder buy-in, to ensure the availability of resources, and to coordinate the various technical and non-technical activities.

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DETERMINISTIC MODELS FOR FIRE PROTECTION ENGINEERING
The Thermal and Fluid Mechanics of Fire

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ABSTRACT

A brief review is presented for deterministic modeling which is taken here to mean predictive methods for the thermal-fluid aspects of fire. This research in fire dominates the output from the fertile period of 1974-1983. It calls for support of fire research at levels that made it productive. Modeling here includes formulas developed by the experimental process at that period which has been invaluable to the engineer. Research funding has been all but eliminated for fundamental studies in fire. These fundamental studies are essential for developing the infrastructure of the discipline and practice of fire protection engineering. A plan is proposed to establish federally funded national centers to support and conduct research for better standards, conduct education and training, and dispense advice and information.

Introduction

Deterministic modeling is a term used often in fire research to mean predictive methods for fire phenomena. Generally this pertains to the physics of fire, since the chemistry in this modeling is relegated to stoichiometry from the known fuel, or data and correlations based on measured yields of the major products of combustion. This modeling deals with the thermal flow properties induced by combustion. Hence a much better title for this discussion might be "the thermal and fluid mechanics of fire". It includes the processes of ignition, flame spread, combustion extent, and burning rate. These processes depend on geometry and fuel properties, and therefore the form and definition of the latter must be addressed. They pertain to processes that occur in the ambient and in confined spaces where the environment can affect their behavior. This includes the behavior of fire in compartments, buildings, structures and vehicles. They may be terrestrial or beyond. In short, the thermal sciences in concert with the combustion processes of uncontrolled fire pertain. As a consequence, the interaction of these processes with people (burn injury, heat stress, inhalation toxicology), structures (fire resistance), special equipment and manufacturing (nuclear reactors, electronics, chip making), and special hazards (radioactive waste fires, pollution, nuclear winter) all come into play. More importantly, the ability to address such issues cannot rest on a response to emergencies. The infrastructure for a knowledge-base needs to be sufficiently developed to deal with issues as they arise, whether they are in the normal scope of fire protection design and analysis or new situations due to disaster or the development of new technologies. In short, fire engineering cannot be relegated to codes and standards

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that have no foundation in science; they must be part of the main stream of science and engineering.

Historical Developments

Fire science has developed slowly and in spurts. The thermal-fluid aspect has dominated the subject of fire science for most of its development thus far. In order to understand the evolution of fire science, it is useful to examine its historical development. The study of fire could not adequately begin without the development of some key areas of science. It is useful to put these developments in perspective. Table 1 shows the birth of significant science disciplines that were necessary for the development fire science. Fire research activities may have begun as early as 1920. These early studies were focused on the establishment of engineering design practices to insure the adequate fire resistance of building structural elements. It is noteworthy that not much has been done in this area over the last 50 years, resting on what was done before. Yet the WTC building collapses have raised our sensitivity to the needs in structural fire resistance. At about 1945 to 1950, a more broad fire research effort began. The studies from this period began to address the dynamics of the fire and the movement of smoke. Damage to people and contents were now considered more important than just the building structure.

Table 1. Suggested Dates for the Development of Modern Science Disciplines

Date	Discipline
1780	Chemistry (Lavoisier)
1850	Thermodynamics (Clausius, Gibbs)
1890	Fluid Mechanics (Reynolds, Prandtl)
1920	Heat Transfer (Nusselt, McAdams)
1930	Combustion (Semenov, Zeldovich)
1950	Fire (Kawagoe, Thomas, Emmons)

In the USA a presidential commission report in 1973, “America Burning”, outlined the needs of the fire service, the fire problem in the USA, and the research needs [1]. The report advocated the need “to strengthen this grounding of knowledge about fire in a body of scientific and engineering theory, so that real-world problems can be dealt with through predictive analyses.” This report, in a time of an acute consumer interest in the safety of products, brought fire research to the forefront in the USA. It helped secure the fundamental grants program of $ 2 million per year from the NSF RANN Program to the newly formed Center for Fire Research at NIST, then the National Bureau of Standards. (Incidentally, Ralph Long, who established the NSF fire program, did a masterful job at enlisting the best scientists and academicians of the country. Also I learned a research management tenet from him when I critically asked him why he had so many grants in flame spread. He replied that it was the only way to make progress through productive debate and convergence on the right answer to issues. This tenet is at odds with modern management that strives to remove redundancy.) The NIST program employed nearly 125 at its peak, but at about 1983, it came under attack due to changing government policies. The fundamental grants program dropped from $ 2 million as initiated in 1974 to $ 1.2 million where it stands today. Fire research and safety has suffered accordingly as government attitudes changed and funding waned.

State of Thermal-Fluids Fire Modeling

The state of the art for fire modeling can be measured by the ability to present a consistent and generalized mathematical formulation for its phenomena. This state can be measured by the number of recognized handbooks and textbooks that exist. These are few in number and not couched in the same pedagogical form as familiar texts in the thermal-fluid sciences. It is interesting to note that the NRC underwrote the McAdams text for McGraw-Hill in 1933, because McGraw-Hill did not want to publish it [2]! The SFPE Handbook of Fire Protection Engineering [3] probably is the best barometer of the state of the art. Published first in 1986 it is now in its 3rd edition. However, in my opinion, the new editions only build sales and do not disseminate any significant new knowledge. The primary development of knowledge occurred when the basic research program of Ralph Long and the good funding years of the Center for Fire Research existed (1974-1983).

Some discussion of the form of modeling results should be discussed. Many associate modeling with computer prediction. This is a narrow view and misses the significant contribution from experimental results. The latter leads to correlations, based on theory, which provide the backbone of formulas for analysis and design. They are the main substance of the thermal-fluids science of engineering and populate the fire literature as well. These correlations are necessary because the phenomena are too complex to be predicted directly from the fundamental laws of physics. Issues of turbulence, radiation and chemistry prohibit exact solutions. These correlations provide the ingredients of system models, known as zone models for compartment fire analysis. In them, the correlations provide the transport relationships for the conservation equations. In the more fundamental CFD approaches, these correlations provide the experimental basis for validation. Hence, the need for specific experimental studies and accurate measurement techniques should be at the forefront of any modeling discussion. I will not address the CFD approach, except to say that these require their own modeling, and direct simulation will have to wait for larger computers. Even when such computers exist, the need for individual formulation of the physics is necessary for engineering application. In fire investigation analysis, I rarely resort to the computer. The physics needs to be estimated first, before seeking improved resolution without, necessarily, an increase in accuracy.

Progress over the last 50 years of fire research has laid a good foundation to demonstrate that a wide range of engineering methods have been developed. Like all areas of engineering, the methods can be improved and refined to improve their generality and accuracy. Some used to think fire was too complex to synthesize by engineering formulae, but this has been dispelled. Current knowledge will allow prediction in the following areas:

1. Dynamics of fire plumes for simple geometries.
2. Dynamics of smoke flow under ceilings.
3. Dynamics of room fires and flashover.
4. Dynamics of ignition, flame spread and burning rate for simple geometries.
5. Primitive results for the suppression of fire and its agents.
6. Smoke movement in simple building geometries from room to room.

Given sufficient funding in fundamental research, prediction accuracy in these areas can be improved and expanded. But fundamental research must be systematically conducted or the knowledge-base will weaken, and the needed expansion will not occur. I emphasize that this research, although some see fire as an applied area, <u>is fundamental</u>, and is essential for this neglected, immature area of science. Although the above list of areas demonstrates competence in predictive methods for fire phenomena, they are far from complete. For example, one might be able to predict flame height in the open, but not its length along a ceiling, out of room, or out of a building. This is incomplete knowledge that tantalizes the practicing engineering, and leads to potential errand analysis. However, in addition to extending the knowledge in 1-6, I list several distinct areas that have been neglected or bear study:

7. Ventilation-limited and fully-developed fires in confined spaces.
8. Heat flux by fire.
9. Turbulent combustion application to fire and buoyant phenomena.
10. Smoldering
11. Measurement techniques for flow and thermal measurements in fire.

This research is necessary to provide the engineering infrastructure to insure society with proper assessment of fire behavior for safety design and for investigation. One can count the fire deaths and the cost of fire as motivators for change, but how can we afford to live in a technicological world and still be subjected to medieval fire tests and regulations.

Flammability Testing.

There is no uniformity in the methods to assess the flammability of materials. Tests vary between countries, and even within government agencies. Rarely can a scientific rationale can be made for the flammability test method. There is no universal criterion to assess flammability, nor can it be directly related to the fire scenario of relevance. This is a serious and a complex problem. Scientists work on idealizations of products and materials, and regulators demand robust, reproducible tests. This is an area that demands more science and more connection to reality. A recent GAO report on Fire Safety says: “The nation’s system for developing standards and testing products to certify their compliance with those standards is complex. The system consists of a decentralized, largely self-regulated network of private independent standards-development organizations, testing laboratories, and government agencies."[4] Technical objective input needs to be provided in this development process. The federal government needs to insure that this happens.

Fire Safety Design and Performance Codes.

Motivating factors for including engineering methods in fire safety design are (1) the reduction of cost, (2) the maintenance of architectural integrity, and (3) the elimination of constraining regulations. Government policies on deregulation have led to legislation in the United Kingdom and in New Zealand to promote the seeking of alternatives to the specific fire regulations. Australia and Japan have also introduced fire safety performance practices into its national building codes. This has opened the door to engineering as an alternative to the "plank-by-plank" language of regulations. Consequently, there has been increasing interest by regulators and standards organizations to embrace the use of engineering methodology in fire safety design. Most regulatory codes provide for an alternative to the prescriptive requirements if equivalence can be demonstrated. This is a challenge for the engineer, and is becoming a bigger part of the dialogue between the fire protection engineer and the authority responsible for administering the regulations. As a result, the knowledge-base of fire science has become more disseminated, but its potential for being used incorrectly has increased.

Just as with the measurement of product flammability, there is a challenge here for fire science. The current fire science knowledge-base has demonstrated and has stimulated the use of engineering methods. In the USA, litigation claims in fire damage suits have encouraged a progressive view of engineering methods for fire. Indeed, the US Supreme Court has required that testing and analysis form the allowable expert opinion in court testimony. This is a natural consequence of fire science becoming available, and lawyers recognizing that valid scientific expertise could help them. Unfortunately, the legal community does not contribute to open research. The ability for the performance code process to grow and have economic and safety benefits can be a catalyst for more needed fire research. A process is necessary for insuring that fire safety design and performance codes are the standards of the future. This will insure measurable safety and more clearly display the weakness of the codes.

Fire Investigation.

Fire science expertise has been recognized to help explain fire accidents and crimes of arson. Governments have convened boards of inquiry that have included fire scientists to help understand fire tragedies of significant public impact. Examples include the fires following the earthquake in Kobe, the Kings Cross fire in London, and the recent TWA 800 explosion. In the USA, the National Transportation Safety Board (NTSB) has unique authority to investigate any significant transportation accidents including fire. In recent years the Bureau of Alcohol Tobacco and Firearms (ATF) was given the federal authority to investigate federal arson crimes, and as a consequence has established a trained nationwide team that can immediately respond individually or in force to a fire scene. Their interest in fire science has culminated in federal funding of the first national laboratory for the study of fire pertaining to arson. The lack of an appropriate investigative analysis for the fire-induced collapse of the WTC buildings (3) dramatically underscores the attention that fire safety receives at the science level. It is great that NSF stepped up with fast-track grants for WTC research, but more is needed.

Fire Engineering Education.

Institutions formally granting degrees in fire safety (protection) engineering, or providing special subprograms in fire engineering, are increasing around the world. I count about 25 programs and growing. They include, beyond the USA, Sweden, UK, N. Ireland, Japan, China, New Zealand, Australia, and Russia. Our program at the University of Maryland has graduated about 700 with a BS degree since 1956 and about 60 MS students since 1990. I am told that the fire program at the University of Lund is the most popular curriculum in Sweden, apparently due to its career path into officer positions in the fire service. The fire service has recently motivated the University of North Carolina at Charlotte to begin a fire engineering program with the same objective. Unfortunately this is not a view shared by all, but it is clear that the general support for fire safety engineering education is growing. Yet as an engineering discipline it has a challenge to demonstrate its scientific competence and market its profession into traditional and new career paths. While in some countries the fire service is recognizing the need for trained scientific personnel, in general the fire service has lagged in its appreciation of fire safety engineering. Yet the fire service is an area that can absorb a large population of students. Current educational institutions in the US cannot fill this potential need.

Issues

Opportunities for Research.

Research in fire does not start at the high-tech level; it is an immature science but has demonstrated its viability as a discipline in its own right. An investment must be made to develop the same systematic knowledge-base for fire engineering that the field of thermal science has experienced. It must catch up. This knowledge-base is essential for sound engineering design and fire investigation. The impact to society is an assured measure of safety that is more realistic than our current practice, and more flexible in its application. This should and must be done through a scientific process. The routine design should still be done by specifications based on engineering, but the extraordinary design needs a performance code process.

Needs in Education and Training.

The field of fire protection engineering is virtually unknown. Many positions are filled without the proper background. This will continue as long as the practice is empirical and code driven. The educational process must keep pace with the demands for change. Those currently in the practice of fire safety must have access to available professional education to afford them the ability to understand and react to this change. Formal engineering education needs to be supported through the development of research and texts.

Barriers.

The barriers to change are the entrenched practices of standards bodies and testing laboratories, and the intransigence of industry to objectively promote safety. The administrative standards infrastructure is sound and working, but it needs to develop a technical infrastructure based on science. Industry is astute enough to digest change with scientific rationality.

Role of the Federal Government.

NSF needs to examine its reluctance to support education and basic research for fire. I was told by a NSF program manager "fire was applied, but combustion was basic research". This of course is ridiculous, but these biases stifle fair consideration. There is much that NSF has done to promote and develop basic research in fire through its program in the 1970's and its evolution to the NIST grants program for fire. But those funds have withered, and need to at least be brought back the to intent of "America Burning".

Certainly, NIST should continue to be the focal point of fire research and development in the USA, and standards should be its focus. Currently, the NIST effort plays an ineffective role in the development of standards. This is not by choice, but by funding ability.

In 1998 I convened an ad hoc group of interested parties (FMRC, NFPA, NIST, SFPE, UL, USFA, etc) for a discussion on the needs of fire research, education and safety in the USA. My concept for a national plan was aired and received significant, but not unanimous, support. I still believe it may still be a way for the US to assume its responsibilities to the public for assured fire safety. This responsibility is one of the federal government. It transcends conservative and liberal philosophies since it helps those that need it, and those that need it (including large corporations and agencies) do not have the ability to develop the safety technology and standards themselves. I propose a nationally funded effort to establish regional centers.

My specific proposed concept is to establish a **nationally coordinated network of "technical centers"** to facilitate fire safety design through education and research linked tightly to the needs of codes and standards. These regional national centers would help to facilitate the implementation and development of performance codes and their evolution from our current prescriptive practices, and would provide the technical bases for input to the standards processes, and needed educational support. I see four components to the centers:

1. **Input to codes and standards**.
   This component would provide support for the needed objective technical input to the normal standards committee processes that currently exist. Those committee processes have an infrastructure and framework for operating. However, they do not necessarily provide technical input from the scientific community. The basic science community in fire is almost decoupled from this process because of the incentives that drive it and the lack of funds to provide the technical base. A direct connection should be made between the standards process and the scientific research community.

This will provide a needed technical dialogue with a clear relevance for the scientific community. This activity can be coordinated between the national centers and standards bodies.

2. Education.

Both degree and continuing education elements are needed. The current set of fire safety practitioners know that science is affecting their practice, but have not had the opportunity to learn from these developments in a deliberate manner. Hence, distrust, anxiety, and over-expectations are emotions that arise among the field of practitioners. In the USA, we have 1 UG fire-engineering program, 2 graduate programs, and several 4-year fire technology programs. These are insufficient to promote the accurate implementation of a performance code. I conceive that the proposed centers could dispense educational programs at all levels and could network distance learning programs as well.

3. Technical Advice.

Just as programs involving manufacturing and agricultural extension services provide information, I would see that a component of the fire safety centers could follow a similar practice. This can be done in many ways. It could consider doing work under contract, directing people to qualified firms, or provide technical information. This is an essential component that is needed for local fire safety approvals and enforcement agencies try to deal with the demands of code modifications, alternatives and interpretations.

4. Research.

Although a sufficient knowledge-base on fire science and engineering methods has developed since the 1970's, it is insufficient to sustain a complete performance code process. Actually, much of the U.S. knowledge-base was established when funding for fundamental research was plentiful in the 1970's. Since then we have seen a significant reduction in a national investment for fire safety research. In 1974 -1981 the research budget for university research from NSF, and then from NIST, was $ 2 million; now in 2002, is a paltry $ 1.1 million. A minuscule amount of the costs of fire safety are invested back into research to answer key questions. As technology advances, the economic and human threats from fire change in ways that prescriptive codes do not anticipate. We can not afford to have immeasurable, non-technically-based fire safety prescriptions for new technologies that can have such widespread potential impact on life safety, economics and security.

I would envision a new research program established to capture the interests of leading scientists in order to maintain a scientific community-base on the subject of fire for a direct link to applications in the codes and standards.

Conclusions

1. Deterministic models for fire have demonstrated the viability of useful engineering analysis and are key to the implementation of performance codes.

2. The current regulatory process needs to create a mechanism for producing scientific information to support current and future standards.
3. The funding for fire research is woefully inadequate in insure a measured level of fire safety.
4. A plan is proposed to establish national centers to develop the infrastructure for technically based fire standards.

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Fire Protection Engineering Tools

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Introduction

Within the context of this document, fire protection engineering tools include deterministic fire hazard analysis models and probabilistic fire risk assessment methodologies. These tools permit the hazards and risks associated with fire to be evaluated quantitatively in terms of physically meaningful units of measure. The development of these tools over the past few decades has prompted, as well as permitted, the development of frameworks for performance-based fire safety analysis, design and regulation of buildings. Continued development and refinement of these tools and methodologies are needed to more fully implement rational performance-based approaches to building fire safety, which hold the promise of permitting more cost-effective fire safety designs with better known levels of safety, risk and uncertainty.

Fires of hazardous proportions are extremely complex chemical and physical phenomena involving turbulent reacting flows at high temperatures, where the highly nonlinear effects of thermal radiation dominate. Unlike controlled combustion processes where the mixing of fuel and oxidizer are regulated, such as in internal combustion engines and furnaces, fires involve unregulated mixing and reaction of fuel and oxidizer. Thomas [1] has suggested that fire be defined as "gaseous combustion without taps," in recognition of its uniquely unregulated nature. As noted by Thomas, the fire controls the air flow, through buoyancy-induced entrainment and chimney effects, while also controlling the supply of gaseous fuel by the thermal feedback to the condensed fuel from the gaseous combustion zone and the hot smoky gases. Despite the complexity of the problem, substantial progress has been made in characterizing the environments produced by fires in enclosures. Considerably more progress can be made with additional research.

Deterministic fire hazard analysis models

Quintiere [2] notes that the term deterministic modeling is often used in fire research to mean predictive methods for fire phenomena, commonly referred to as fire modeling. Generally, this pertains to the physics of fire, with modeling of the chemistry of fire relegated to specification of the stoichiometry of a known fuel or to the development of data and correlations based on measured yields of the major products of combustion. The physical modeling of fire generally deals with the temperatures, flows, smoke concentrations and smoke movement induced by combustion. Hence, Quintiere suggests that a more descriptive term for fire modeling might be the thermal and fluid mechanics of fire.

Fires in enclosures develop in a series of stages, which Mowrer [3] has called:

- The fire plume / ceiling jet stage;
- The enclosure smoke filling stage;
- The preflashover ventilated stage;
- The postflashover ventilated stage.

In terms of this sequence of fire development in enclosures, fire models have been developed in reverse order, with postflashover fire models developed first, followed by models of the other stages. To a large extent, this sequence of model development has followed and been motivated by increasing computer power.

The first enclosure fire models addressed the postflashover ventilated stage of fire development in terms of a one-zone well-stirred reactor concept. As noted by Thomas [1], interest in postflashover fire conditions was driven in large part by pressure from structural engineers to deal in a quantitative way with the loads imposed by fire on a structure. Following the fire-induced collapses of three high-rise buildings at the World Trade Center in New York on September 11, 2001, there is renewed interest in this issue on the part of structural and fire protection engineers.

In many respects, the postflashover stage of enclosure fires has been the easiest to analyze for a number of reasons, including:

- thermal conditions within the enclosure are relatively uniform throughout the volume of the enclosure, permitting a one-zone, well-stirred analysis to be relatively accurate for predicting average gas temperatures within the enclosure;
- the burning rate within the enclosure is regulated by the rate of air flow into the enclosure, i.e., the fire intensity is ventilation-controlled;
- The rate of air flow into the enclosure is regulated by the ventilation factor, $A_o\sqrt{H_o}$, that arises due to the buoyancy of the hot gases within the enclosure.

As a consequence of these last two points, the burning rate within an enclosure is known to a higher level of accuracy during the post-flashover stage than during the earlier stages of an enclosure fire.

Models based on the one-zone, well-stirred reactor concept were developed in the 1950s by Kawagoe in Japan [4], in the 1960s by Magnusson and Thelandersson in Sweden [5] and in the 1970s by Babrauskas and Williamson in the United States [6]. Relatively little notable work was done on the modeling of post-flashover fires in the 1980s, but during the 1990s, Thomas and Bennetts in Australia [7] performed small-scale experiments in long and wide enclosures with single ventilation openings that call into question many of the long-standing assumptions regarding the behavior of post-flashover fires, particularly with respect to the duration of such fires. This work had stimulated renewed interest in the topic of post-flashover fire severity even before the events of September 11, 2001.

Modeling of the pre-flashover vented stage of enclosure fires began in earnest in the United States in 1972, with the NSF-RANN sponsored Home Fire Project under the direction of Emmons at Harvard University in collaboration with Factory Mutual Research Corporation. This work [8], and related work [9] at the National Bureau of Standards (now NIST), gave rise to the conceptualization and development of the two-zone enclosure fire model. The two-zone modeling approach uses the concept of thermodynamic control volumes, with the application of conservation equations to assess the relatively uniform conditions within different control volumes. In a two-zone fire model, the control volumes nominally include the hot smoke layer beneath the ceiling and the cool lower lower above the floor of a room. These zones, assumed to be separated by a distinct interface, arise due to thermal stratification caused by the buoyancy of the fire gases. Quintiere [10] provides an overview of the zone modeling approach, including discussions of the application of the conservation equations and of the various submodels typically used to address different phenomena such as fire heat release, plume entrainment, vent flows and boundary heat transfer.

A large number of two-zone enclosure fire models were developed and refined through the 1980s and early 1990s [11], with the FAST/CFAST model developed at NIST [12] representing the current state-of-the-art of multi-room two-zone fire models and probably the most widely used zone model in the world today. With the emergence of CFD fire models as practical engineering tools, the development and use of zone fire models is beginning to diminish.

Modeling of the enclosure smoke filling stage of enclosure fires was an early outgrowth of the two-zone modeling effort. Zukoski [13] published the seminal paper on enclosure smoke filling in 1978 and Cooper [14] developed the ASET model shortly thereafter. Walton [15] adapted the ASET model for use on the personal computers that were just starting to come into widespread use in the early 1980s. Even today, almost 20 years later, variants of the simple ASET model are still used in fire protection engineering practice, to such an extent that the computer model evaluation task group of the Society of Fire Protection Engineers is currently evaluating the accuracy of the ASET model.

Preliminary analysis of the fire plume / ceiling jet stage of enclosure fires was undertaken by Thomas during the 1950s [16]. Considerable work on ceiling jets was done during the late 1960s and early 1970s, principally at Factory Mutual Research Corporation. Axisymmetric fire plume and ceiling jet temperature and velocity correlations developed by Alpert in 1972 [17] are still widely used, particularly in the predominant model for predicting fire detector and sprinkler activation times, the DETACT model, the concept for which was initially developed by Heskestad [18] during the mid-1970s before being developed in its current form by Evans and Stroup [19] during the mid-1980s.

Models of preflashover vented fires as well as enclosure smoke filling models require plume entrainment submodels in order to calculate the transport of mass, species and energy from the lower layer to the smoke layer. This need stimulated increased interest in the topic of fire plume entrainment during the 1970s and 1980s, with a number of investigators [20-22] performing experiments and developing correlations for the entrainment of air into axisymmetric plumes based on the seminal work of Morton, Taylor and Turner [23] on buoyant plumes during the 1950s.

One significant limitation of zone models is that they do not predict fire-induced flows from first principles. For example, a zone model requires a plume entrainment submodel in order to calculate the rate of mass flow from the lower layer to the upper layer. Plume entrainment correlations have only been developed for a limited range of idealized plume geometries, including axisymmetric plumes and line plumes. Consequently, the accuracy of zone models diminishes as real conditions diverge significantly from the idealized conditions upon which the submodel correlations are based. This imposes a significant limitation on the accurate application of zone models and has been a motivating factor in the development and application of field fire models.

During the 1980s, the application of computational fluid dynamics (CFD) models to enclosure fire simulation began in earnest, with much of the early work performed in the United Kingdom. As noted by Cox and Kumar [24], many of the assumptions and simplifications associated with zone fire modeling are unnecessary for CFD modeling because in CFD modeling the full set of field equations, expressing the conservation principles for mass, species, momentum and energy, are solved numerically, subject only to the boundary conditions of the problem, at least in theory.

CFD models come much closer to first principles than zone models in terms of expressing the conservation principles, but for practical problems they still require elements of modeling because full resolution of the time and length scales involved in the reacting turbulent flows associated with fire is not practical with current computers. In particular, turbulence, combustion and radiation typically require the specification and selection of appropriate models. Direct numerical simulation (DNS) of combustion is now used for research purposes [25], but is expected to remain a tool of the basic combustion research community for many years to come [24].

Two types of CFD model are now in fairly widespread use in fire protection engineering. These modeling approaches differ in their treatment of turbulence. The Reynolds-averaged Navier-Stokes (RANS) model solves only for time-averaged properties, with the turbulent fluctuations and transport processes in these averages addressed by means of turbulence models. The k-e turbulence model is typically used in RANS models. Large-eddy simulation (LES) rigorously computes the larger vortices associated with fire-induced flows, but requires models to address sub-grid scale phenomena, including combustion. As noted by Novozhilov [26], LES provides a level of accuracy closest to DNS because it resolves the large scale motions of the flow while requiring modeling only for the smaller scales.

In LES, large-scale flows are solved exactly, with modeling needed only for the small-scale motion. Because the small eddies that are being modeled rather than calculated contain only a small portion of the total turbulent kinetic energy, the flows computed by LES are usually less sensitive to the approximations involved in the small scale turbulence modeling. The LES approach to modeling fire using CFD has become the most popular approach in recent years due to the release by the National Institute of Standards and Technology of the Fire Dynamics Simulator fire model based on LES [27].

Initial applications of CFD models to fire generally were directed towards smoke movement and smoke control problems. These problems typically involve relatively small fires in relatively large spaces, where the effects of radiation and oxygen vitiation on combustion are negligible. For these applications, details of the fire itself are not too important; the fire simply serves as a source of heat (buoyancy) and combustion products. For these applications, the fire is typically specified and the movement of smoke resulting from this specified fire is calculated by the CFD model. For this type of application, hydrodynamic aspects of the models are most important. It is these hydrodynamic aspects of the models that are closest to first principles, so this type of application can be addressed with a relatively high level of accuracy, provided the boundary conditions are well known.

There is increasing interest in application of the CFD models to predictions of ignition, flame spread and burning rate, including the important effects of thermal radiation and oxygen vitiation on these processes. These are significant issues for many, if not most, hazardous fire situations. These topics are at the cutting edge of fire science and considerably more research is required to permit the prediction of fire development. The ability to accurately predict fire development, rather than just the consequences of a specified fire, represents the greatest challenge, as well as the greatest opportunity, for advancing the scientific basis of fire hazard assessment.

So far, this discussion of fire hazard assessment has only addressed the modeling of fire development and consequences. A key aspect of fire protection engineering is the design of systems to mitigate the consequences of fire. These include fire detection and alarm systems, as well as fire suppression systems, with automatic sprinkler systems being the most popular form of automatic fire suppression. The topic of fire detection and alarm systems is addressed elsewhere in this report.

McGrattan [28] and Grant, et al. [29] provide overviews of fire suppression with water sprays. McGrattan notes that relatively crude water suppression submodels have been incorporated into various CFD-based fire models over the past decade, while in their comprehensive review, Grant, et al. note that relatively little research had been done on fire suppression following World War 2 until a resurgence of interest in water mist as a replacement for Halon in fixed fire protection systems. Both reviews reflect the relative lack of knowledge on detailed fire suppression mechanisms and the currently empirical nature of fire suppression system design. Further research can reduce this empiricism and provide a more scientific basis for fire suppression system design.

Probabilistic fire risk assessment methods

Fires in buildings are relatively rare events, but they can have very large and extreme consequences. From an economic standpoint, it can be argued that the objective of fire protection engineering should be to minimize the total expenditure for fire, including the costs of direct and indirect fire losses as well as the costs of public and private fire protection. Evaluating these costs is a daunting task; determining the proper levels and allocations of expenditures for cost effective fire protection is even more daunting. Evaluating the costs of fire is made even more difficult by the life safety aspects of the fire problem. While precise cost optimization may be an unattainable goal, probabilistic fire risk assessments are important to the understanding of fire safety, particularly the state of knowledge regarding the dominant contributors to fire risk.

Internationally, a number of countries have been moving in the direction of risk-based fire safety regulation. Notable among these countries are Australia and Canada, where researchers have been collaborating for many years on a comprehensive risk-cost assessment model. In Australia, this work is embodied in the Fire-Risk (formerly CESARE-Risk) model [30], while in Canada, a model called FiRECAM (for Fire Risk Evaluation and Cost Assessment Model) [31] is being developed. These risk-cost assessment models employ an event-based modeling approach in which events are characterized by discrete time and probabilities of occurrence [32]. The models have been applied to office and apartment buildings, with the performance of the fire safety design assessed in terms of two decision-making parameters: 1) the expected risk to life (ERL) and 2) the fire cost expectation. Similar concepts have been espoused in the United States [33], but have not been developed in terms of a comprehensive model.

In the United States, performance-based approaches to fire protection design has been developed fairly recently in terms of a framework guidance document [34], performance-based options to prescriptive code requirements [35] and performance-based codes [36]. These performance-based approaches depend on the selection of design fire scenarios. One of the distinguishing aspects of fire scenario selection is the potential for intentional acts of incendiarism as well as accidental ignitions. Another is the dynamic interaction between the fire scenario and the level of protection provided. These distinguishing features require different types of analyses than used for natural hazards such as earthquakes.

Siu [37] provides an overview of potential research and development needs for probabilistic methods in fire safety assessment. Siu defines "probabilistic methods" as methods of analysis whose results are stated in terms of probabilities (or related quantities, e.g., frequencies). They are distinguished from probabilistic solutions methods (e.g., Monte Carlo simulation methods), which can be used to solve deterministic as well as probabilistic methods. Siu notes that probabilistic methods of engineering analysis are designed to quantitatively address the uncertainties inherent in safety analysis. They provide an indication of central tendencies as well as a measure of the uncertainties associated with the central tendencies. They not only provide a language and the tools to support analysts in making clear statements about the limitations in their results, they also provide a means to convey important information to decision makers who wish to assess and use the analysis results.

As noted by Siu [37], the application of probabilistic methods to fire safety assessment can range from complete scope probabilistic safety assessments (PSAs), which identify potential scenarios, their consequences and their probabilities, to more focused assessments of the uncertainties associated with the prediction of particular phenomena under tightly specified conditions. The models used in these assessments can be deterministic or probabilistic and the solution methods used to solve these models can also be deterministic or probabilistic. A complete, formal uncertainty analysis for both deterministic and probabilistic models requires: a) an assessment of the uncertainties in the model input parameters, b) the propagation of these uncertainties through the model structure, and c) the estimation of uncertainties associated with the model structure itself. Methods are available to perform the first and second steps in relatively routine applications, but considerable development work remains to be done on methods supporting the third step.

Siu [37] identifies a number of key research needs in the area of probabilistic methods for fire safety assessment. These include: the development of efficient numerical methods for solving complex problems as well as the guidance for selecting methods appropriate to a specific problem at hand, the quantification of uncertainty in a set of model parameters when current evidence is weak, and the quantification of uncertainties associated with the structure of a given model. He notes that it is not clear if there is an understanding of the risk-dominant fire scenarios for different buildings and facilities in sufficient detail to identify and evaluate potentially effective risk management strategies. He argues that a large number of fire safety assessments may be necessary if a more detailed understanding of these scenarios is needed. While not necessarily an opportunity for "breakthrough" research, this is a crucial enabling step in the identification of measures that should lead to real improvements in national fire safety.

Summary and Conclusions

The term "fire modeling" is a misnomer for most applications because the fire itself is typically specified and it is the consequences of this specified fire that are being calculated. Thus, a more accurate term for most applications would be "fire consequence analysis" rather than "fire modeling." Herein lies the most fundamental limitation of fire modeling and the area where substantial improvements are needed to advance the current state of fire hazard analysis modeling.

The current state-of-the-art in predicting fire development is not nearly as advanced as the current ability to calculate the consequences of a specified fire. Significant improvements are needed in the understanding of the chemical and physical processes involved in the unwanted burning of combustibles in buildings, including the high-temperature and flammability properties of materials. Continued development is also needed in the models used to predict fire development, particularly in their treatment of the combustion process and radiative heat transfer in enclosure fires.

In order to develop cost-effective engineering designs for fire protection, risk-based, or performance-based, analyses are needed. Performance-based approaches to fire safety design are just now emerging and are not yet comprehensive. Much of the development of performance-based approaches to fire protection has borrowed from other low-probability high-consequence hazards, such as earthquake. But it is important to recognize that fire has some significant differences when compared with extrinsic hazards such as earthquakes. Foremost among these differences is the potential for intentional fires, which renders meaningless the concept of a return period for fire (i.e., the concept of a 100-year building fire is meaningless). The interaction between fire protection design and fire magnitude is also an important difference that needs to be explored.

Developments in fire protection engineering tools are expected to be evolutionary, not revolutionary. Nonetheless, significant progress can be made with research into both deterministic fire hazard assessment and probabilistic fire risk assessment.

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LARGE-SCALE MODELING OF FIRE SUPPRESSION WITH WATER SPRAYS

Kevin McGrattan[1]

Abstract

The mechanisms underlying fire suppression by water can be divided into gas and solid phase phenomena. Numerical models of these phenomena are dependent on the level of detail given to the combustion and the fuel pyrolysis processes. Presently, models of gas phase suppression are limited by the use of simple zero or one-step combustion mechanisms in large-scale simulations. Detailed numerical models of small-scale combustion systems exist, but these models are hard to apply at room or building scale. Models of solid phase suppression are limited by the lack of well-accepted, robust pyrolysis models that have enough physical detail to accommodate the inclusion of water impingement. Several lumped parameter models of solid phase suppression by water have been developed over the past decade, but these models do not necessarily work well within a CFD model framework. The challenge to the modeler is to inject more physics into the solid phase suppression models and to simplify the physics of the gas phase to bring the two parts of the problem into the same conceptual framework.

Introduction

The problems inherent to modeling fire suppression are, not surprisingly, similar to those inherent to fire modeling in general. Indeed, the governing mechanisms can be divided into two categories – gas phase and solid phase. In the gas phase, an agent – water, CO_2, *etc.* – interacts with the fire, slowing or stopping the reaction of fuel and oxygen. The equations describing the transport and mixing of the various species are not subject to debate, and there exist fairly good numerical solvers of these equations for small-scale combustion systems. On the other hand, the solid phase phenomena, even without the introduction of the suppression agent, is not well-characterized by a set of equations accepted by the research community. Ironically, solid phase suppression phenomena are more amenable to engineering correlations in large-scale simulations, even though gas phase phenomena have a better theoretical foundation. The challenge to the modeler is to inject more physics into the solid phase suppression models and simplify the physics of the gas phase to bring the two parts of the problem into the same conceptual framework.

In the discussion to follow, we will discuss the challenges associated with modeling both gas and solid phase fire suppression by water after first discussing the often non-trivial modeling of the suppression device, *i.e.* sprinkler, fire hose, extinguisher, *etc.*, and the transport of the agent to the fire. The suppression agent of interest here is water simply because the author has more experience with it. More information about suppression of fire by water can be found in an overview article by Grant *et al.* (2000). Suppression with gaseous agents is primarily a gas phase problem, and these issues will be discussed in terms of water vapor as a suppressing agent. The detailed chemistry of suppression agents will

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not be discussed. Finally, we will include some examples of fire suppression calculations performed to date at NIST to point out the possibilities and limitations of modeling fire suppression.

Getting the Water to the Fire

Before we can discuss suppression in either the gas or solid phase, we must consider how the agent is delivered to the fire. The most common fire suppression technique is via a water spray, either from a fire hose or an automatic sprinkler system. An entire industry is built around designing, installing and maintaining sprinkler systems in buildings. A good design requires that the sprinklers activate in a timely manner and deliver water to the fire in sufficient quantities to at least control its spread. Numerical models are used in the design process to predict activation times, and to a limited extent the subsequent suppression of the fire by the water droplets. Predicting activation is the least difficult part of the problem, followed by the calculation of the water spray, followed by the suppression of the fire. In the discussion to follow, we will follow these different steps.

Sprinkler Activation

The temperature of the sensing element of a given sprinkler is estimated from the differential equation put forth by Heskestad and Bill (1988) at Factory Mutual

$$\frac{dT_l}{dt} = \frac{\sqrt{u}}{\mathrm{RTI}}(T_g - T_l) - \frac{C}{\mathrm{RTI}}(T_l - T_m) \tag{1}$$

Here T_l is the temperature of the thermally-sensitive mechanism (link), T_g is the gas temperature in the neighborhood of the link, T_m is the temperature of the sprinkler mount (assumed ambient), and u is the gas speed flowing past the link. The sprinkler is assumed to activate when the link temperature reaches a prescribed value. The sensitivity of the detector is characterized by the value of the Response Time Index (RTI), a roughly constant parameter for a given sprinkler which is a measure of the link's thermal capacity divided by the heat transfer efficiency between the hot gases and the link.

$$\frac{\mathrm{RTI}}{\sqrt{u}} = \frac{\rho_l\, c_l\, V_l}{hA} \tag{2}$$

The amount of heat conducted away from the link by the mount is indicated by the "C-Factor", C. Both are empirically determined from a test device in which a sprinkler is quickly "plunged" into a small, hot wind tunnel. Recently, Ruffino and di Marzo (2001) have provided an additional heat sink to the equation due to small water droplets from other activated sprinklers. The term is proportional to the mass flux of water in the neighborhood of the sprinkler, and the proportionality constant has been found to be relatively constant for different types of sprinklers.

This activation model for a sprinkler is widely used in the fire protection community in both CFD and lumped parameter ("zone") models. Given the variety of sprinkler designs, it provides a relatively simple model whose accuracy is comparable or better to the governing flow calculation. Except for the addition of source and sink terms, like the water droplets or radiation heat flux, it is not anticipated that a better model will be developed in the next decade.

Sprinkler Spray Characterization

Sprinkler spray characterization will remain largely empirically-based because each sprinkler has its own unique design that makes predicting the initial water spray difficult. To simulate the sprinkler spray, we need to know the initial distribution of the droplet size and velocity. Measuring these quantities has proven to be very difficult and still very expensive. The most promising technique for measuring droplet size is through Phase Doppler Interferometry (PDI) (Widmann, 2001); and droplet velocity through Particle Image Velocimetry (PIV) (Sheppard, 2001) Both are non-intrusive, laser-based techniques that require very expensive equipment and skilled technicians with a high level of training in laser diagnostics. This is worrisome because calculations of this type should be cheaper than experiments. If high level modeling of challenging industrial fire scenarios becomes more routine and starts to show potential benefits to sprinkler manufacturers and building owners, there ought to be more investment in the measurement techniques required for input data. The Catch-22 is that it is hard to show benefits with little information about the various sprinkler designs and fuels.

Water Droplet Transport, Heat and Mass Transfer

Once the initial distribution of water droplet size and velocity distributions have been provided, the transport of the droplets through the hot, smoke-filled gases and the exchange of mass and energy between the droplets and the gas can be handled using fairly well-accepted correlations found in most any heat transfer text book. The droplets are treated in a Lagrangian fashion, where a single computed droplet will represent many more actual droplets. This approach has been called the "superdrop" concept (Kumar *et al.*, 1997). Again, one may argue that any of the half-dozen different empirical relations is too simplistic, and in response the modeler can systematically refine the treatment of the droplets. However, a point of diminishing returns will soon be met because uncertainties associated with the suppression of the fire will far out-weigh those associated with the tracking and evaporation of largely spherical water droplets. Indeed, one of the biggest challenges in modeling a sprinkler spray is not the flight of the droplet through the hot gas, but rather the pooling, dripping and absorption of the water onto and into a complicated pile of burning and non-burning commodity. Indeed, the goal of many sprinkler systems is not necessarily to extinguish the fire but rather to control it and stop its spread. What happens to the water on non-burning surfaces is thus equally important to what happens to it on burning surfaces. Moreover, burning objects rarely maintain their original shape and consistency, and trying to model every aspect of the process is an exercise in futility.

Solid Phase Suppression

The fundamental physics and empirical relations describing the heat transfer between a droplet of water and hot gas are fairly well-accepted and reasonably easy to apply in a

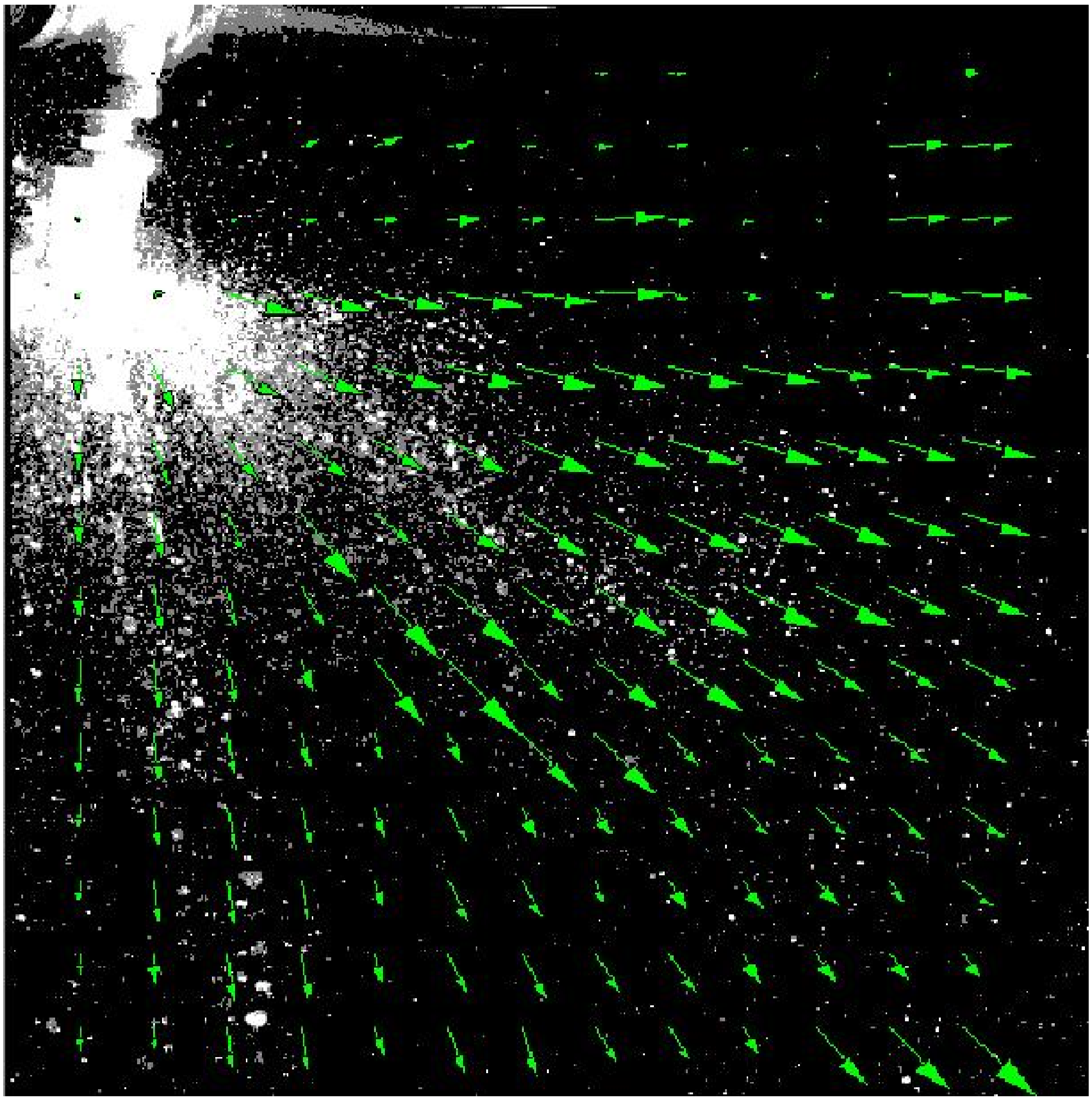

FIGURE 1: PIV image of a pendant sprinkler, showing the velocity vectors of the droplets. Reprinted courtesy of David Sheppard, Underwriters Laboratories and Richard Lueptow, Northwestern University.

numerical model. However, when the water droplets encounter burning surfaces, simple heat transfer correlations become more difficult to apply. The reason for this is that the water is not only cooling the surface and the surrounding gas, but it is also changing the pyrolysis rate of the burning fuel. If the surface of the fuel is planar, it is possible to characterize the decrease in the pyrolysis rate as a function of the decrease in the total heat feedback to the surface. Unfortunately, most fuels of interest in fire applications are multi-component solids with complex geometry at scales unresolvable by the computational grid.

To date, a significant amount of work in developing engineering models to describe the decrease in burning rate by water application has been performed at Factory Mutual. An important paper on the subject is by Yu *et al.* (1994). The authors consider dozens of rack storage commodity fires of different geometries and water application rates, and characterize the suppression rates in terms of a few global parameters. Their analysis is based on energy balances at the fuel surface, and it yields an expression for the total heat release rate from a rack storage fire after sprinkler activation

$$\dot{Q} = \dot{Q}_0 \, e^{-k(t-t_0)} \tag{3}$$

where $\dot{Q}_0$ is the total heat release rate at the time of application t_0, and k is a fuel-dependent (usually linear) function of the water application rate. The exponential nature of the decrease in heat release rate has been observed in a wide variety of fire tests. It is not surprising that there is an exponential relationship since the fuel pyrolysis rate is tied to the heat fed back from the fire.

Unfortunately, this type of analysis is based on global water flow and burning rates. Equation (3) accounts for both the cooling of non-burning surfaces as well as the decrease in heat release rate of burning surfaces. In a CFD model, the cooling of unburned surfaces and the reduction in the heat release rate are computed locally and separately, thus it is awkward to apply a global suppression rule. However, the exponential nature of suppression by water is observed both locally and globally, thus it can be assumed that the local burning rate of the fuel can be expressed in the form (Hamins, 1999)

$$\dot{m}''_f(t) = \dot{m}''_{f,0}(t) \, e^{-\int k(t)\,dt} \tag{4}$$

Here $\dot{m}''_{f,0}(t)$ is the burning rate per unit area of the fuel when no water is applied and $k(t)$ is a linear function of the local water mass per unit area, m''_w, expressed in units of kg/m^2,

$$k(t) = a \, m''_w(t) \quad \mathrm{s}^{-1} \tag{5}$$

Note that a is an empirical constant.

Understanding how various standard commodities burn and how they respond to water ought to be less empirically-based. Solid phase pyrolysis models need to be developed that retain enough of the fundamental physics to accommodate a better description of suppression, yet that are consistent with the assumptions and limitations of a large-scale simulation. A strategy for doing this is to apply current CFD techniques to model relatively small-scale standard test apparatus, and eventually move to larger scale. It is unclear how to describe the burning of real commodities, which are mixtures of cardboard, plastics, woods, *etc.*, other than with the simple lumped parameter models developed to date. It is hoped that at a minimum, we will have a way of relating the burning rate of the fuel to the heat feedback to the surface based on the thermo-physical properties of the fuel rather than simply an exhaustive series of experiments that are often too expensive to perform given the wide variety of fuels burning in a single fire. This is possible now with a limited number of pure fuels, liquids especially, but hopefully this list can be extended in the future.

Gas Phase Suppression

Most large-scale fire models track fuel and oxygen, and the major products of combustion, via a single mixture fraction variable or by way of multiple transport equations for the individual species. Because the flame cannot be resolved on grids whose cells are on the order of tens of centimeters, empirical rules must be used to ascertain the chemical heat release rate. Often the burning rate is closely tied to the parameters used to model the subgrid scale turbulence. In the case of a mixture fraction approach, it is assumed that fuel and oxygen burn instantaneously when mixed. Regardless of the combustion model, in cases of large-scale, well-ventilated fires, the various models work in a reasonable way in the sense that the fuel is consumed and the energy is distributed onto the computational grid. However, if a fire is in an under-ventilated compartment, or if a suppression agent like water mist or CO_2 is introduced, fuel and oxygen may mix but may not burn. The physical mechanisms underlying the phenomena are complex, and all the simplified models suffer from an imprecise estimation of the temperature and local strain rate in the neighborhood of the flame sheet. A good overview of the physical mechanisms behind water mist suppression is given by Mawhinney *et al.* (1994).

Sub-grid scale modeling of gas phase suppression and extinction is still an area of active research in the combustion community. Until reliable models can be developed for building-scale fire simulations, simple empirical rules can be devised that prevent burning from taking place when the atmosphere immediately surrounding the fire cannot sustain the combustion. In such a model, a single set of state relations can no longer be applied, since now some fuel may be mixed with the other combustion products. To account for the deviation from the ideal state relations, at least one other scalar quantity in addition to the mixture fraction would have to be tracked in the calculation. This increases the cost of the calculation, but may provide enough information to make reasonable assessments of the affect of the water vapor on combustion.

Examples

Following are two examples of calculations performed at NIST with the Fire Dynamics Simulator (FDS), a CFD model that uses large eddy simulation techniques to model fire (McGrattan *et al.*, 2001). The first example looks at the performance of a sprinkler system in a large warehouse. The issues here are the activation of the sprinklers, the trajectory of the water droplets, and the suppression of the fire that consumes box loads of commodities stored on steel racks. Suppression is achieved mainly through direct contact between the water and the burning surfaces. The second example looks at the suppression of a large heptane spray fire within a mock-up of a shipboard machinery space. Mist nozzles are used to flood the entire compartment volume with very fine water droplets. The rapid evaporation of the droplets cools the hot gases and displaces the available oxygen within the compartment. Here suppression is almost all gas phase.

Rack Storage Fires

A few years ago, in parallel with large scale tests conducted by the NFPA Research Foundation, computer fire models were used to predict the outcome of fire suppression tests in mock-ups of large warehouses and warehouse retail stores (McGrattan, 1999) (Figure 2). A series of bench scale experiments was conducted at NIST to develop necessary input data for the model. These experiments generated data describing the burning rate and flame spread behavior of the cartoned plastic commodity, thermal response parameters and spray pattern of the sprinkler, and the effect of the water spray on the commodity selected for the tests (Hamins, 1999). It was found that the outcome of the large-scale calculations was very sensitive to these inputs, especially the thermal properties of the commodity. In addition, predicting the spread of the water over and between the pile of boxes was very difficult, nullifying any gain in accuracy achieved by the bench-scale tests.

What made the model work reasonably well was the fact that the water spray and "dripping" behavior parameters were tweaked until a match between computed and observed water density patterns on the floor was obtained. Hundreds of hours were needed to roughly characterize one fuel and one sprinkler because the characterization was almost all empirical – little of it was based on fundamental physical models because the phenomena were so very complex. As a result, users of the FDS model were not able to apply it easily to other commodities and sprinklers; a problem that persists to this day.

Water Mist

A more complex example of the new algorithm is shown in Fig. 4. Here a mist sprinkler system is installed in a simplified machinery space whose dimensions are 16 m by 10 m by 8 m. The 6 MW fire is fueled by a series of heptane spray burners lined along the top of a steel box centered in the compartment. Eight mist nozzles are positioned at the ceiling, 4 m apart. Four nozzles are positioned above the 2 m by 2 m opening centered along the longer wall, 0.5 m above the floor. The nozzles are activated a short time after the ignition of the fuel burners. The small water droplets evaporate due to both the high temperatures in the upper smoke layer, and the absorption of thermal radiation from the fire. The water vapor displaces oxygen and the water evaporation cools the compartment, both of which weaken the fire. The numerical algorithm appears to handle the evaporation and transport of the water vapor, but a problem remains in predicting the change in burning behavior. Presently, the FDS contains a mixture fraction combustion model that assumes an infinitely fast reaction between fuel and oxygen regardless of temperature. Dilution of the air by smoke, exhaust gases and water vapor is predicted in the model, but the unburned fuel due to a lack of oxygen eventually burns somewhere in the compartment, even though the lower temperature in reality would not sustain this burning. Thus, the focus of attention needs to be turned back towards the combustion routine so that the suppression of the fire in an underventilated space can be handled better. Even in the absence of a sprinkler system, there is a need to better understand the weakening of a fire in an underventilated

FIGURE 2: Photograph of a rack storage fire, courtesy Underwriters Laboratories, Northbrook, IL.

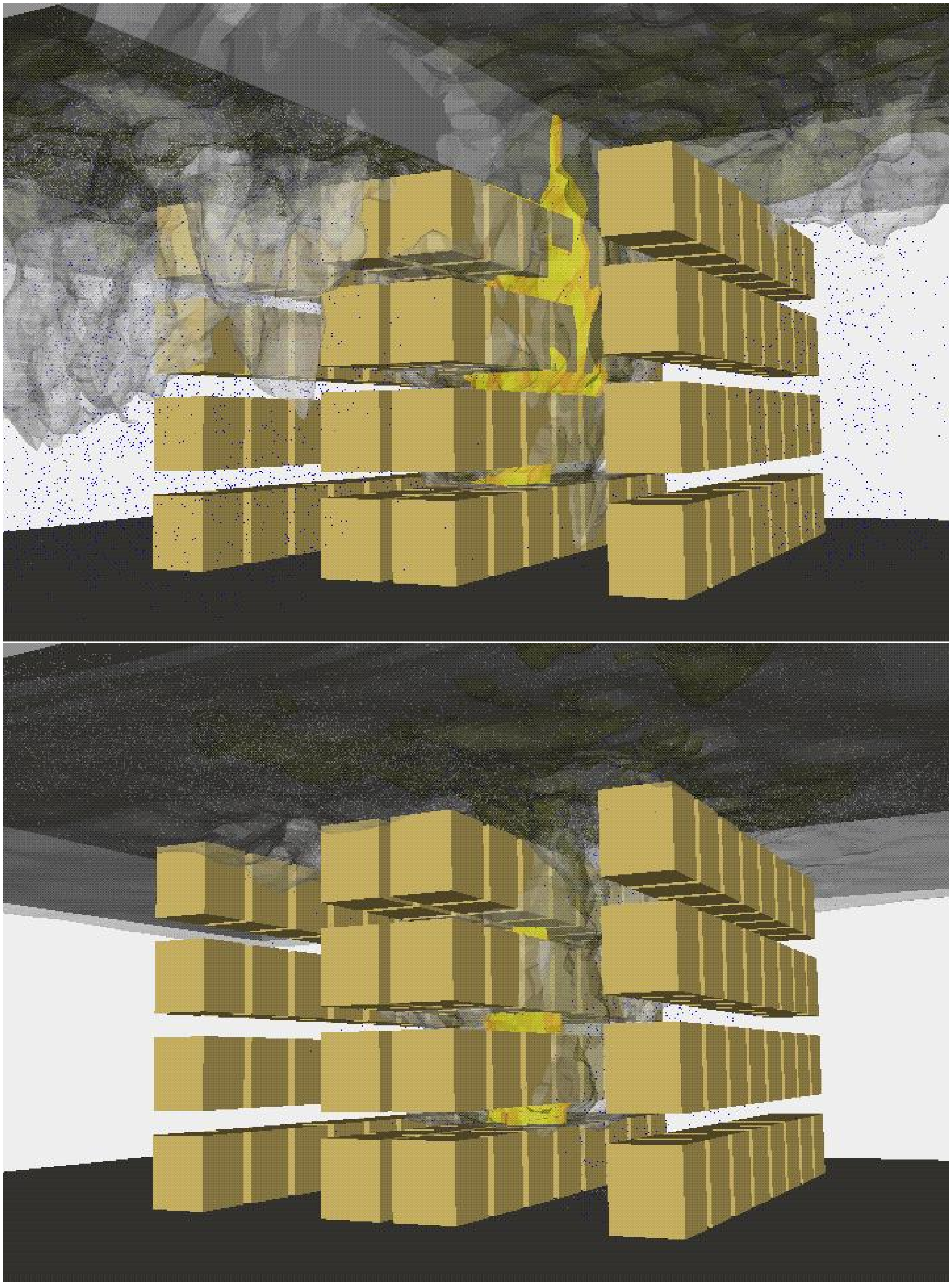

FIGURE 3: Snapshots of two simulations of a rack storage fire. In the top picture, the fire is ignited beneath a draft curtain, which interferes with the sprinkler activation. In the bottom picture, no draft curtains are present.

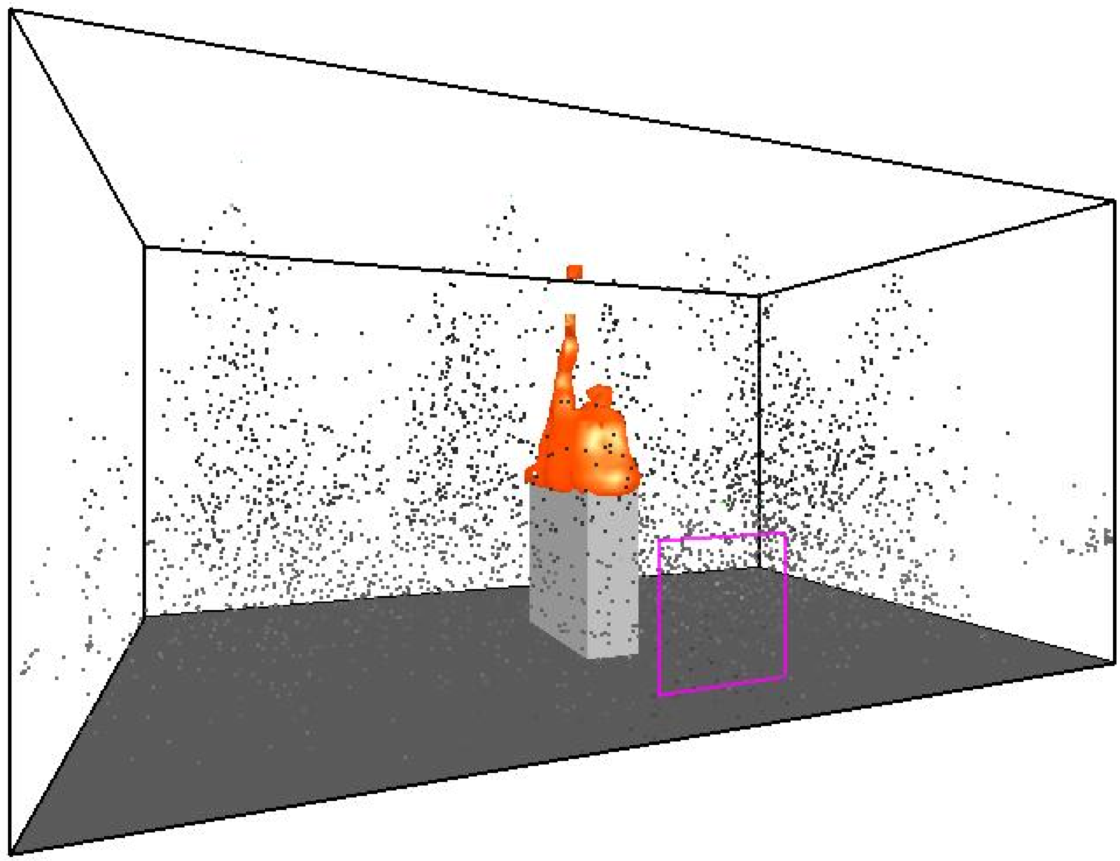

FIGURE 4: Simulation of a mist system suppressing a large heptane spray burner fire. Shown is the outline of the flame and the water droplets.

compartment.

Conclusions

Relatively crude water suppression sub-models have been incorporated into various CFD-based fire models over the past decade. Thus far, the models can be used for qualitative analysis of sprinkler and mist suppression systems. In some cases, it is possible to carefully select the necessary parameters to match the results of actual large-scale tests, then use the model to simulate similar large-scale tests that cannot be performed because of cost. As research in this area continues, it is inevitable that some physical features of the problem will receive a more detailed treatment than others. The challenge to modelers is to develop the various physical sub-models at the same pace, so that no one part of the problem outpaces another. The degree of accuracy of the overall model is determined by its weakest element. Maintaining a consistent level of accuracy is difficult in an academic environment because of the highly specialized nature of most university endeavors. Consider the chemical kineticist, the fluid dynamicist, the material scientist all being told that what they are doing is not of use in a particular fire model, not because it is bad research, but rather that it is inconsistent with the overall level of accuracy in the model. Of course, eventually these detailed mechanisms may be of use, but when? To get to that point, the models that have been developed to date have to be used for both research and practical problems. CFD still remains out of reach for many because of cost, limited computer power, difficulty of use. Getting beyond this obstacle means making CFD models run faster, cheaper and easier. Simply making the computer program run is not always easy, and it takes time and a critical mass of users to iron out numerical bugs even before the real problems inherent to the limitations of the sub-models can be addressed. Once one gains experience with a given model, the research needs will become clearer because the limitations of the model will be understood in terms of a concrete application.

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UNDERSTANDING HUMAN BEHAVIOUR IN STRESSFUL SITUATIONS

Guylène Proulx, Ph.D.[1]

ABSTRACT

The events of September 11, 2001 have shocked the public imagination regarding the safety of highrise buildings. Prior to these events, the reluctance to evacuate upon hearing the fire alarm signal was regularly observed in highrise buildings. Following the tragic events of September 11, many highrises were totally evacuated on minimal cues. The perception of risk seems to have been heightened right after the event but will this condition last over time? Highrise buildings are seldom meant to be totally evacuated. The strategy used instead is phased evacuation or a protect-in-place approach. Today during an emergency, are highrise building occupants prepared to stay in and wait to be instructed before leaving the building? Studies should investigate the risk perceived by highrise building occupants since September 11 and how these perceptions might change over time. Further studies should compare highrise occupant intention of response during an emergency and actual response through unannounced drills. Authorities, architects and engineers need these findings in order to appropriately design buildings, fire safety systems, training materials and instructions provided to occupants during an emergency.

Background

The content of this paper was greatly inspired by discussions with different colleagues, particularly with Drs. Rita Fahy, Brian Meacham and Jim Flynn. In partnership with these scientists, a study proposal was submitted in December 2001 for a Small Grant for Exploratory Research Proposal to the National Science Foundation (Fahy et al., 2001). Although the proposal was unsuccessful at the time, the questions and variables tackled are still of the utmost importance for the future of fire safety in highrise structures. Consequently, these issues are reiterated here in a different format.

Highrise Evacuation

The events of September 11, 2001 and particularly the World Trade Center towers attack, fire and subsequent collapse have had a significant impact on the public perception of risk and safety in highrise buildings. In the days following these events a large number of highrise buildings were totally evacuated on minimal cues, in some cases a simple rumor was sufficient to vacate thousands of office workers to the street. This heightened state of perceived risk could not last forever, people would not be able to function under such a high level of stress (Seyle, 1979). However, the question remains: are there some

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lasting effects that could influence occupant response during a future emergency? If such effects exist how do they impact fire safety engineering and will this affect change over time?

It is important to understand that modern highrise buildings which are over 25-storeys in building height are seldom meant to be fully evacuated in the event of a fire. The evacuation strategy in such highrises is usually to instruct building occupants through a voice communication system to remain in place while the emergency is dealt with, whereas a phased evacuation or relocation of occupants is carried out. In a phased evacuation the occupants closest to the fire are evacuated or moved to other floors first, while floors above the fire floor evacuated successively upon receiving instruction. Occupants on some floors, particularly under the fire floor, may not need to evacuate at all and might essentially protect-in-place.

In the September 11 incident, many occupants of the South Tower began to leave the building, on their own, right after the first plane struck the North Tower. For the survivors from the uppermost floors of the South Tower, this decision saved their lives since, later on, a plane hit their floors. This is particularly important in light of reports that occupants of the South Tower were told, through the voice communication system, that because the incident was contained to the North Tower, they did not need to evacuate and it was safe to stay or return to their desks. Although this instruction may have been appropriate at the time it was issued, many occupants who followed the instruction could well be among the victims. After the second plane struck, and after the two towers collapsed, many members of the public have been left with the impression and mistaken belief that the instructions given to the building occupants were erroneous. Many people have also taken from the events of the day a new expectation that the collapse of a highrise building may be inevitable during any fire, failing to appreciate the extreme differences between a “typical” highrise fire and one caused by a large aircraft loaded with fuel.

The events of September 11, which received unprecedented and sustained media coverage, may have changed the public perception of risk in highrise buildings (Finucane, 1999). People who work or live in highrise structures may be fearful that a similar attack will be made on their building or that a fire could bring the structure to collapse. If people have developed a new attitude toward safety in highrise buildings, their response in case of an emergency might be different from what could be expected prior to September 11. The design of buildings, fire safety features and fire safety plans might need to be modified to accommodate the new attitude of highrise building occupants.

Behaviour in Stressful Situations

It is recognized that every person involved in an emergency will feel some form of stress regardless of their age, gender, past experience, training or cultural background. This stress is not an abnormal reaction; on the contrary, stress is regarded as a necessary state to motivate reaction and action (Seyle, 1979). The performance of the person in dealing with a stressful situation will depend on the task demands, the environmental conditions and the subject himself or herself (Wesnes & Warburton, 1983). In order to make a decision the person will process information, perceived in the environment or drawn from past experience (Janis & Mann, 1977).

Decision-making during an emergency is different from day-to-day decision-making for three main reasons. First, there is much more at stake in emergency decisions - often the survival of the person and of the people he or she values the most is at play. Second, the amount of time available is limited to make a decision before crucial options are lost. Third, the information on which to base a decision is ambiguous, incomplete and unusual, further it is usually impossible to look for more appropriate information due to the lack of both time and means to get information (Proulx, 1993).

During a fire, the nature of the information obtained, the limited time to react and the assessment of danger will create a feeling of stress. It is argued that this stress will be felt from the moment ambiguous information is perceived until well after the event when the person has reached safety (Lazarus & Folkman, 1984). During the course of the event, the intensity of stress experienced will vary as a function of the information newly-perceived and the assessment of the decision taken. The media and public in general often mentioned the potential of mass panic, imagining a crowd that suddenly wants to flee danger at all cost, even if it implies getting trampled or crushed in the process. Although these types of behaviour are extremely rare in fires and have never been reported in highrise fires, the expectation that people will panic is very strong. This schemata is very much nourished by the media and movie industry who like to play on strong emotional images. In fact, 'panic' in the form of irrational behaviour is rare during fires and researchers have long ago rejected this concept to explain human behaviour in fire. From around 200 accounts of the World Trade Center survivors published in the media, panic was seldom mentioned instead many emphasized the calm and altruistic behaviour of the evacuees.

The expectation of 'panic' has been a favored argument put forward to delay warning of the public during emergencies (Sime, 1980). Such delays in informing the occupants have contributed to subsequent flight behaviour and crush of people who had only a few seconds left to react and escape once the situation unexpectedly got out of hand. Consequently, researchers are pleading for early warning to the public, providing occupants with as much information as possible to support them in their decision making process (Donald & Canter, 1990; Proulx & Sime, 1991).

The reality of human behaviour in highrise building fires is somewhat different from the 'panic' scenario. What is regularly observed is a lethargic response to the fire alarm, voice communication instruction or even the initial cues of a fire (Proulx, 1999). Unless very well trained, occupants are usually reluctant to leave their floor and are prepared to stay on location. Phased evacuation or a protect-in-place approach are seen as less disruptive by occupants. Staying on location during actual fires is sometime the official fire safety plan (Proulx, 1998) or the chosen response by occupants (Proulx, 1996).

In modern highrise buildings over 25-storeys in building height, it is neither practical nor feasible to conduct full evacuation of the building. Not all occupants have the capacity to travel down so many floors. Further, in order to obtain reasonable evacuation times, wider or multiple means of egress would be necessary which would make the building economically non-viable. Therefore, the buildings and fire safety features are designed to allow occupants to stay on location or to evacuate in sequential order.

If people believe they are not safe in highrise buildings and choose not to comply with fire safety instructions telling them to evacuate only when directed, the risk to all occupants of the building could increase tremendously due to injuries associated with uncontrolled egress. For people living and working in highrise buildings, how they perceived their risks, process information, and make decisions for their safety will impact on how engineers should design buildings and safety systems.

Safety systems in buildings have to account for what can realistically be expected from people in emergency situations. For example, if it is known that it takes on the order of 2 or 3 minutes for people to leave their apartments in a highrise tower, it would be inappropriate to make assumptions that people will leave within seconds. Likewise, if it is known in highrise buildings that all people will leave on every floor at once instead of a few floors at a time, the ratio of egress capacity to egress time will change, and building design will need to accommodate this response. If the events of September 11 have affected people's confidence in the structural integrity of highrise buildings, it is possible that they will not remain in place for phased evacuation, no matter what they are told, and the impact could be significant.

Research Needed

There are 5 dimensions needing immediate attention regarding human behaviour in a highrise building fire. This research should focus on the impact of the attack, fire and collapse of the World Trade Center towers have had on issues of risk perception, communication, and trust in the information given for occupants of highrise buildings.

1. Study how perception of risk in highrise buildings has changed since September 11, 2001.
2. Explore the impact of highrise risk perception on intended behaviour in future emergencies.
3. Observe unannounced emergency evacuations in highrise buildings varying evacuation strategy and information provided to occupants to access actual response.
4. Compare actual evacuation behaviour with intended behaviour.
5. Conduct longitudinal studies to assess the impact of September 11 over time.

This research effort could involve developing and conducting surveys of highrise occupants, planning and monitoring emergency evacuations, conducting post-evacuation surveys and post fire surveys.

Conclusion

To understand the implications of September 11, it is necessary to investigate the actual occupant perception of risk in highrise buildings and how people intend to react during an emergency while assessing how these factors might change over time.

To conduct such studies, appropriate funding is required. There is still this myth out there that social science is easy and shouldn’t cost as much as applied sciences. Research into human behaviour is certainly not easy and tends to be lengthy and costly. Funds should be readily available to start investigation immediately after fires.

Authorities, architects and engineers need these findings in order to appropriately design highrise buildings, fire safety systems, training materials and instructions provided to occupants during an emergency. The way highrise buildings are designed today, may very well change in light of the events of September 11. If occupants are no longer prepared to comply with the procedure elaborated in the fire safety plan, important changes will be necessary in existing and future highrise buildings to prevent major disasters.

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HUMAN FACTORS CONTRIBUTIONS TO BUILDING EVACUATION RESEARCH AND SYSTEMS DESIGN: OPPORTUNITIES AND OBSTACLES

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Abstract

Human factors research and design methods provide data collection and analysis methods relevant to a wide-range of evacuation research questions, from higher-order cognitive processes to basic design issues such as egress widths. Research questions include the discovery of human goals and the cognitive demands imposed by their pursuit, the achievement of situational awareness and its influence on decision making processes, cooperation among people with different roles, and the inclusion of adaptive human agents in the design of performance-based fire safety systems. However, many obstacles are evident, the foremost of which is the lack of funding directed towards research into the human factors fire safety systems. Other difficulties include the over reliance on codes and standards and the lack of user-centered design curriculum for fire safety researchers, engineers, and practitioners.

Introduction

The field of human factors (alternatively called "ergonomics") has contributed to solving many design challenges where people interact with technological systems. The human factors field has a remarkable record of contributions to other engineering fields—including aviation and military systems, computer-human interactions, and workplace safety. The potential for cost-effective innovation is great, especially in view of the large stock of existing buildings. The field of human factors can yield designs that better support the actions and decisions that enable safety systems adapt to chaotic events that play out in unforeseeable ways.

The National Research Council recognized the importance of the field by organizing a standing committee on human factors in 1980. "Ample evidence exists—from aviation accident reports to job task analysis—documenting the importance of investing in human factors and the sometimes tragic results of failing to consider its contributions." (Rouse, et al., 1997)

Advantages of user-centered system design

We maintain that the fire safety community needs to broaden its view of what constitutes a fire safety system where the actions of people largely determine successful outcomes. In our view, a fire safety system is comprised of *all* relevant components, *including* people, that play significant roles in mitigating the effects of fire. (Groner, 2001). Everything that can support the goals of an evacuation should be the concern of the systems' designers—including procedures and training.

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Systems-centered approaches traditionally used by fire protection engineers are ill suited to designing systems that take full advantage of human as well as technological agents. "Traditional system-centered design treats users as just another resource to be assigned and optimized to meet operational goals" (Stanney, et. al, 1997; p. 639) However, favorable outcomes from building evacuations necessarily depend on the actions taken by people, and people are not mechanical systems components that dependably react with assigned predetermined responses. Instead, people select and process information that helps them pursue their goals of adapting to stressful, ambiguous, and dynamic situations. To account adequately for the goal-seeking information-processing reality of human behavior, we believe fire protection engineers should understand how and when to change from systems-centered design to user-centered design. "User-centered design…considers users' roles and responsibilities as the key design objective to be met and supported by advancing technologies." (Stanney, et. al, 1997; p. 639)

Example: Alarm signals

Non-vocal alarm signals provide an example of the limitations of systems-oriented design. If people were "just a resource…to meet operational goals," alarm signals would evoke the assigned responses from building occupants. However, from a user-centered perspective, alarm signals provide little information on which to base human responses. There is no information about the likelihood that the threat is real, its location and severity, and the viability of response options. From a user-centered perspective, poor responses are to be expected. From the user-centered perspective, the designer is responsible for building a system that provides information sufficient for people to choose a reasonable course of action. Human factors provides the research and design tools that can guide this expanded view of systems design.

Research questions addressable using human factors engineering approach

To help explain the potential for designing fire safety systems from a user-centered perspective, the following section presents a few research questions concerning building evacuations, along with speculation how human factors professionals approach the problems.

How can we discover what goals people pursue during evacuations, along with the relevant physical and social features of their environments that influence their actions?

The behaviors of people are responses to the situations in which they find themselves. It follows that systems design should take into account people's understandings of social and physical attributes of the situations in which they are likely to find themselves. Many human factors professionals use "contextual inquiries" to obtain relevant data, and to consolidate it into "work models" that describe informational flows, the use of artifacts, constraints imposed by social roles and the physical environment, etc. (Beyer and Holtzblatt 1998).

Example: Deference Behavior in Evacuations

Methods adapted from contextual inquiries can be applied to the understanding of deference behavior exhibited by people using stairways in high-rise office buildings. Based on evacuation drill observations by Pauls and Jones (1980), evacuees coming down an exit stairwell tend to defer their progress to people entering the stairwell from a lower floor. Deference behaviors imperil people on higher floors who have a more-urgent need to evacuate than do those on lower floors. Do people believe they are relatively safe in the stairwell and people entering need the same security? Do they believe that people from lower floors take precedence in getting out? Do people automatically apply tendencies to be “polite”? We need to understand why this occurs to design systems that will reliably hold some people back so that those most endangered have priority access to the exits.

How can we research the cognitive demands imposed by pursuing goals in emergencies situations?

In understanding how we can research and design systems that support building evacuations, human factors professionals commonly rely on cognitive task analyses to develop systems requirements (Schraagen 2000). A conventional task analysis describes the steps required to accomplish a goal, producing a standard operating procedure to be applied *without variation* in response to a defined scenario. However, given the stressful, chaotic, and ambiguous situations generated by real emergencies, the importance of cognitive demands imposed by tasks is transparently important. Cognitive task analyses are used to understand how expectations, perception, memory, mental models, and decision-making influence human performance in responding to building emergencies.

Example: finding safe routes of egress

Cognitive task analyses can provide insights into how systems designers support the real goals of people during an evacuation. For example, Groner (1998) discussed the use of smoke detection systems to inform building occupants about which routes of egress are tenable. Similarly, simple devices can inform persons in residential units whether it is safe to leave doors in a more effective manner than the problematic process of feeling the door for heat.

How can we build models that integrate human performance and physical engineering representations into overall systems views of building evacuations?

Ideally, Performance-based design solutions would reflect an integrated systems understanding that includes how people adapt to achieve desirable systems goals. Deterministic probabilistic representations that model the probabilities of events are inherently limited, because they can only model fixed responses to defined scenarios (Groner, 1999). However, in the real world, emergencies are started and play out in unpredictable ways.

Example: Integrated systems representations of building evacuations.

Groner and Williamson (1997, 1998) have investigated the use of desirable system states to model systems that integrate physical engineering and human behavioral responses to emergencies. Other human factors professionals have examined similar problems in other contexts. These types of representations are needed to optimize the allocation of functions between human and manufactured agents. (Sharit, 1997)

What factors enhance and inhibit the achievement of situational awareness?

Situational awareness refers to the person's perception of context, especially as regards to how the environment helps or hinders them in their pursuit of goals. An important part of situation awareness concerns a person's ability to project how the environment will change in the future. In a fire emergency, mistakes can be avoided by achieving good situational awareness.

Example: When to direct people to leave a residential high-rise building.

Incident commanders need to achieve good situational awareness to know when and where to order building occupants to evacuate or relocate. Proulx (2001) discussed an incident where an evacuation was ordered after exits stairs were no longer tenable, injuring people and forcing many to abandon their evacuations and seek refuge. Investigations of the factors that facilitate and interfere with incident managers' understanding of situations would help systems designers support this crucial decision.

What factors impact the quality of cooperation among building emergency teams, management, operational engineers, and emergency responders?

Building evacuations involve complex and dynamic relations among people in many roles. A significant body of research has revealed that social roles are important during responses to fire emergency. The extent to which these people can successfully collaborate is important to achieving good situational awareness and finding a viable response. Social roles can facilitate or interfere with these crucial tasks.

Example: How to do social roles affect what information is used in achieving situational awareness of incident managers?

Human factors professionals have been making progress in their understanding of how systems design can improve the effectiveness of inter- and intra-team cooperation (McNeese, et al 2001). For example, Cockpit Resource Management concerns the cooperative work of aviation flight crews (Wiener, et al. 1993), and provides a useful model for research that can reveal problems and suggest solutions in the role relations among building emergency teams, managers and operating engineers, tenants, and emergency responders.

How do people really make decisions and how can training, procedures, and technology be used to support them?

Naturalistic decision-making refers to the process of how people decide of courses of action in real world settings. Klein (1989) observed firefighters to discover that decision-makers did not consider the value and probabilities associated with alternative courses of action. Instead, they try to achieve a fit between the perceived situation and their memory store of mental schema. Accordingly, good situational awareness results from the availability of schema that match well to situational features. An example of current salience is the development and use of expert schemas that can help incident commanders predict progressive building collapses.

Example: Video Monitoring of Egress Activity in Exit Stairwells

Pauls (1994) proposed the use of video monitoring of exit stairwells as a means to improve decision-making during building evacuations. Video cameras in the exit stairwells, especially at the exit discharge area, can potentially help incident managers to adjust the numbers of people using particular stairwells, assess interference between descending evacuees and ascending emergency responders, etc. Human factors research is needed to understand how to design video systems that enhance decision making rather than adding to an overload of information.

Obstacles to the Use of Human Factors in the Design of Building Evacuation Systems

More than anything, research into the intersection between human factors and fire safety needs funding. For a decade or so, starting in the mid-1970's, the National Institute of Standards and Technology funded seminal research into human behavior and fire that yielded important insights. For example, "panic" was once believed to be prevalent during fire emergencies. We now know that altruism is common during emergency evacuations, and that people spontaneously form "convergence clusters." We also know that prior role behaviors carry over to emergencies, that people persist in their tasks even when confronted with seemingly obvious signs of danger, and that ambiguous information leads to confusion and mistakes. (For a review of fire-related human behavior research, including a focus on evacuation, see Pauls, 1999.)

Even while funding for research into human behaviors and fires diminished, the field of human factors made notable advances. We believe that adequate funding of research on human factors related to evacuations will yield insights that can significantly improve the design of fire safety systems.

We are failing to conduct timely research about human and organizational factors during emergency building evacuations. The 9/11 World Trade Center evacuations are only the most recent and salient examples. During these evacuations, we do not know whether deference behavior was common, the evacuees' reasons for their decisions, how well building emergency teams and professional responders worked together, whether people anticipated the impending structural collapse, the role of changes made subsequent to the 1993 bombing—the list is too long to complete here.

We need funding to support the technology transfer of human factors methodologies to better understand and design fire safety systems. The video monitoring recommended by Pauls (1994), especially in relation to the 1993 evacuation of the World Trade Center towers, would have permitted rapid determination of exactly how many people came out of each exit as well as the exact flow volume over the course of the evacuation. Following the 2001 terrorist attack, the recommendation gained even more potency as it became very important to identify the evacuees (and emergency responders) individually as well as to determine the exact number, something that was in dispute both in the 1993 and 2001 incidents.

Unfortunately, research related to human factors applications to fire safety has been largely ignored. For example, there are several university-based centers for the research of natural disasters, and the National Science Foundation supports rapid responses to such events. However, there is nothing to support a similar response to building evacuations, as evidenced by the recent hearings conducted by the Congressional Science Committee. (http://www.house.gov/science/ hot/wtc/wtc.htm)

Fire safety engineering curricula needs to include human-centered design and associated methods. We believe that fire protection engineers needlessly limit themselves by only recognizing the validity of methods that conform to "standards of engineering practice." A related obstacle is the longstanding professional reliance on legally enforced building codes and safety standards that limits the scope of attention given to safety issues, including fire-related human behavior. Current codes and standards do not take a user-centered approach, even when so-called systems approaches or performance-based approaches are used. One exception to this is found in the *Life Safety Evaluation* applicable to large places of assembly addressed by the *Life Safety Code,* NFPA 101.

Conclusions

The human factors field introduced in this paper provides, in our opinion, the best discipline with which to address evacuation. As described by Pauls (1994, 1999), user-centered systems design should be based on a much better understanding of the five W's of evacuation: What, Who, Where, When and Why. The "One Thing that Absolutely Needs to be Done" is to quickly and carefully study emergency evacuations in large buildings (such as the World Trade Center towers). We can make immediate progress by picking the "low-hanging fruits" of evacuation research. Researching more challenging topics dealing with the cognitive and cooperative demands posed by evacuations will yield more valuable advances.

Fire safety researchers and design professionals will need to change attitudes and broaden their orientations to take advantage of this promising intersection of disciplines. This can best be accomplished through education in user-centered design principles and methods adapted from the field of human factors research and design.

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AVAILABLE DATA AND INPUT INTO MODELS

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ABSTRACT

There is a need for better data to improve our knowledge of human behavior in fire. This data can be used in the development and refinement of evacuation models and in the use of such models. Once collected, human behavior data must be published in peer-reviewed journals and conference proceedings. A central repository should be created to store the data in a format that enhances its use by researchers, fire safety engineers and the regulatory community. The data collection itself must be adequately funded. We need a coordinated effort to collect this sort of information, rather than ad hoc projects when major incidents occurs. Valuable time can be lost in the pursuit and processing of funding. One important method for collecting this data is post-incident surveys and interviews. Although there are some disadvantages to this technique, it provides valuable insight into actions and behaviors in real-life emergencies.

Introduction

Evacuation models are key tools for the evaluation of engineered designs. Fire growth models can predict the spread of smoke and other toxic products throughout a structure. Evacuation models can predict the location of people as they exit the structure. Used together in the evaluation of a design, these models can provide some indication of the risk that occupants might face under a modeled scenario.

Evacuation models vary in complexity, but all rely on data, either in their development (i.e., they are calculation methods based on observations) or as input. The models may simply provide estimates of evacuation times, or they may be intended to more fully simulate occupant behavior, including decisions.

Brief Overview of Evacuation Models

There are different types of evacuation models. There are simple straightforward calculation methods for estimates of evacuation times. These equations or simple computer models may be based on observed movement from drills and experiments.

The next level of complexity is network flow models that handle large numbers of people. These models are useful for benchmarking designs, but they cannot be used to predict what any one person might experience, since they treat the occupants like water in a pipe rather than as individuals.

Behavioral simulation models are the most complex, treating more of the variables related to both movement and behavior. Their added complexity requires tremendous amounts of data for their development, if the assumptions they contain

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regarding behavior are to be based on reality rather then expediency. Their users also need a fuller understanding of the components of human behavior in fire in order to choose appropriately among available options.

Types of Data Needed for Models

Data can be used to develop the equations or algorithms in models or to serve as input to the models. Data is also needed to test the validity of the models.

All evacuation models require data on the characteristics of occupants, their actions during evacuation, delays that may occur, and travel speeds for different types of occupants. Data is needed on, for example:

- delay times, i.e., the time that elapses between when people are first alerted to an incident and when they begin to leave, including the time they may take to prepare for evacuation;
- walking speeds on different types of surfaces, up and down stairs, under different degrees of crowdedness, and for people with a range of physical abilities;
- occupant characteristic, including age, gender, degree of training, familiarity, etc., to account for differences in actions and reactions among the different types of people for different types of occupancies;
- the variety of specific actions people may engage in during evacuation, since these will impact the time people take to leave the building;
- effects of obstructions in travel paths, which can cause delays or block egress; and
- exit choice decisions, which determine travel paths and affect travel times.

Sources of Data

The appropriate methods for collecting the needed data vary, and each collection method has its advantages and disadvantages.

<u>Videotaped observations</u> of actual evacuations are ideal, since they show exactly what different people did, and the elapsed time can be calculated directly from the tape. They will show how long it takes people to react to cues, to seek information and/or prepare to evacuate, and will record their movement (including queueing, walking speed, flows through doorways, in corridors or on stairs, precedence behavior at merges, etc.) The characteristics of their individuals, including any mobility impairments, can be determined from the tape, or can be obtained later in interviews. However, videotapes are rarely available for actual fire incidents, so what is obtained is information that, though valuable, is not directly applicable to decisions and movement of people under actual stressful conditions. Regardless of its limitations, extensive and valuable work in this area has been undertaken in recent years in mid- and high-rise apartment and office buildings. [Proulx et al 1994, 1995a, 1996]

<u>Laboratory experiments</u> have been done to test the effects of smoke on decision-making and travel speed. [Jin 1997, Kubota 2001] Because of ethical issues and

increasing restrictions and outright bans on the use of human subjects, however, researchers rarely undertake such experiments.

Post-incident surveys and interviews can be used to obtain information from survivors of actual fires. This method has been used for a great many years (Bryan 1977 and 1983, Woods 1990, Best 1977, Proulx et al 1995b, Fahy and Proulx 1996). A methodology for conducting post-fire interviews is detailed in (Keating and Loftus 1984). Although these methods will give real-life evidence, there are disadvantages. Recollections and descriptions will be subjective. The elapsed times are not recorded objectively, and the reported times may be distorted. Details can be lost as time passes after an incident, making timeliness of data collection an important issue. Recollections of a group of people may converge over time as they share their stories and meld details.

Research Needs

In order to better understand human behavior in fire, to enhance the effectiveness and completeness of evacuation models, and to provide better information for the users of evacuations model, additional study is needed in a range of areas.

The areas of study involve the need for more data on all the time components of behavior, particularly those that are not a simple matter of speed and distance; data on the variability of those time components; and data or models on the factors driving behavior choices and the variability in time to perform certain actions. Some of the more specific areas are listed and described here:

- effects on counterflows in stairs: what do we know about the impact of firefighters going upstairs while occupants evacuate or of rescuers (e.g., in hospitals or nursing homes) returning for more people?
- movement capabilities of a wide cross-section of society: how much do we know about variations in movement capability by age or by walking impairment?
- evacuation of disabled people: how are wheelchair users expected to evacuate and how long with that take; how might their evacuation impact the overall evacuation flow?
- differences in response to a range of cues: do people respond differently to different types of alarms or different fire cues?
- waking effectiveness of a range of cues: what would be the most effective method or design to awaken people and alert them to a fire?
- delay times before beginning evacuation: what is the effect of being alone, being with others, the types and number of cues, the type of occupancy, a person's experience with false alarms?
- flows on different types of stairway configurations: what do we know about the use of space on stairs, flows on spiral stairs, the effect of the geometry of stairs?
- behaviors: who decides to stay and who decides to go; what is the basis for exit choice; how can we predict stopping and turning back behaviors; who

queues and who doesn't; do we know how to predict an individual's need for rest during long evacuations?

- effects of training of staff and/or occupants: how can we begin to quantify the impact of training of staff or occupants on reducing delay times and/or improving travel times?
- perception of risk: what factors impact perception of risk and how does risk perception impact judgment?
- toxic effects: at what levels do toxic products affect decision making, movement speeds and survival and how do those effects vary among people?
- interaction between people -- how do the presence of social groups impact evacuation delays and movement?
- elevator use: assuming they were safe to use, how would they be used effectively for evacuation, and would they be used by everyone or only by those with mobility impairments?
- alarms: can building occupants recognize alarms and how audible are they throughout a building, given ranges in ambient noise and light levels?

Education and Training

Research in human behavior is a discipline that could benefit greatly from improved partnerships with researchers in the behavioral sciences. (Horasan and Saunders, 2001) Differences in approach to research between physical and social sciences must be bridged so that the best information can be identified and applied to the fire problem.

Once data is collected, it must be put in the hands of the people who can use and apply it. Two international symposia were held in recent years which have helped to focus attention on this research field, which has been an essential first step and the proceedings from the symposia are valuable resources (ISHBF 1998, 2001). However, there were few practitioners in the field of fire safety engineering present at either symposium. They need a place to find the current state of knowledge in human behavior so that they can effectively and appropriately apply available evacuation models. Model developers need access to the data so that they can use it as the basis for assumptions and calculations. Building and fire regulators need the data so that they can better understand and evaluate the analyses of engineered designs. In the overall field of fire safety sciences, researchers studying the physics and chemistry of fire need to appreciate the role of human factors in the use of products, the maintenance of systems, the response to real-world fires, and their vulnerability to fire's effects. This all points to the need for a cross-disciplinary approach to the study of human behavior in fire.

Barriers to Improved Collection and Use of Data

We lack a central repository for research on human behavior in fire. A central storage system for data would require that efforts begin to standardize the collection or reporting of collected data so that retrieval would be simplified. A first attempt to consolidate some of the available movement and delay time data has been proposed, but that was only a very preliminary first step (Fahy and Proulx, 2001).

There are several barriers that exist today that limit our ability to create such a clearinghouse. Much of the data collected over the past few decades was never published, and so, cannot be used. Any data collection project must be published in peer-reviewed literature.

A standard reporting mechanism would allow data from various sources to be compared, without unduly constraining the approaches researchers choose to use. For example, every data set should include a description of the occupancy, the capabilities of the occupants, their number, the fire safety systems present, the effectiveness of those systems and any other information that supplies a context for the data. This would enable researchers to identify the similarities between data sets and allow comparisons or aggregations where appropriate. Aggregated data should be reported in terms of distributions that will capture the range of observations, rather than just summary statistical measures.

And finally, data must be shared. This is difficult when the research is funded by an entity that will claim a propriety right to the data. Government-funded research, however, should be disseminated as widely as possible, so that all can benefit.

Conclusion

Human behavior in fire is clearly an area that would benefit from increased research efforts. If only one aspect of the research had to be given top priority, it should be the timely collection of post-fire incident data. The U.S. Fire Administration of the Federal Emergency Management Agency contracts for the investigation of significant fires. The incidents to be investigated are agreed upon by the contractor and contract officer, with the cooperation of the responding fire department. Very little delay occurs after notification of the fire and the dispatch of the investigation team.

A similar program for the collection of survey or interview data could be instituted. This would reduce the delays that now occur while proposals seeking funding are developed and reviewed. General agreement on approach (which can vary from incident to incident) can be reached beforehand. A schedule for completion of reports and planning for their dissemination would also be agreed. Every incident needs a methodology tailored to that incident, and that unavoidable customization step takes long enough. Coordination with USFA may be necessary, since an on-scene incident investigation, including information on the fire, the geometry of the structure, the presence and performance of fire protection systems, etc., bear on the actions of the occupants in attempting evacuation.

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POSSIBILITIES FOR FIRE RETARDANT MATERIALS - TOWARD SOLVING THE MOST DIFFICULT PROBLEMS

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ABSTRACT

Flammable materials are increasing in our workplaces and in our homes. Flame retardants, although shown to save lives and property, are not used in most plastics and textiles due to cost and adverse effects on other properties. Progress in flame retardant materials has been mostly evolutionary. There are pressing needs particularly for better means for flame retarding the large volume commodity polymers.

Many flame retardant modes of action can be demonstrated, but most have not been fully exploited, for example, heat reflecting additives, endothermic additives, improved char formers, non-carbonaceous barrier formers, dehydrogenation and oxidative dehydrogenation catalysts, improved intumescent systems, char morphology improvers, radical scavengers, and char oxidation inhibitors. Systematic quantitative measurements and basic mechanistic studies of the contribution of multiple additives are needed to find optimum and synergistic combinations.

Training and academic research in flame retardant chemistry in the U. S. has been quite limited. At Polytechnic University, we have been dependent on industrial funding resulting in mainly short-term research goals, and high-risk approaches have generally not been pursued.

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Introduction

There is a pressing need for advanced technology for ignition-resistant, self-extinguishing or slow-burning plastics and wood. The environment in which we live and work is increasingly being loaded with materials with high heats of combustion. At the same time, potential ignition sources such as electrical wiring and devices are proliferating. In housing, urbanization and crowding results in more human involvement in fire ignition. The fastest growing commodity plastics, the polyolefins and the styrenics, are also the ones most difficult to flame retard, especially where cost is a large factor. Present technology uses mainly brominated additives which work well as flame retardants but tend to increase visible smoke and corrosive vapors, and require fairly substantial loadings. Alternative flame retardants for the hydrocarbon-rich polymers, namely aluminum hydroxide and magnesium hydroxide, require very high loadings such that polymer properties are badly impaired. Wood, despite over two centuries of effort, still lacks fully satisfactory flame retardants; those which are used can sometimes cause serious strength loss.

Research Needs

From several decades of personal experience, I believe that aggressive research on new flame retardant systems to find a way out of this problem has been insufficient. Leading research centers are few in the U. S.; NIST is doing a respectable job, and amongst universities,

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Marquette University and Polytechnic have been conducting modest sized projects in this area over the last two decades. Industrial efforts have been more evolutionary than revolutionary. Newer products coming out of industry, particularly phosphorus and bromine types, are improved but still recognizable descendants of older types. One of the more novel systems, the nanoclays seem to have had their start at Toyota in Japan. These seem to be more useful in suppressing heat release than in retarding ignition or bringing about self-extinguishment, although we recently found that we could achieve self-extinguishing properties by using nanoclays plus other selected flame retardants to provide a synergistic action (Weil and Rao, unpublished).

Some excellent flame retardancy research depends on the development of novel polymers. Prof. Pearce and I reviewed "fire-smart polymers" which are designed to crosslink when exposed to fire (Pearce, Weil and Barinov, 1999). Prof. Riffle at this meeting describes flame retardant thermoset composites. Much elegant work was done in the Cold War period on highly fire-resistant designed polymers, costly enough that virtually none of them have found civilian use. Indeed, when cost, processability and other industrially important factors are considered, the "fire-smart polymers" are unlikely to replace the commodity polymers. Thus, we are left with a serious problem. We have proposed at various times several aggressive approaches to the problem (Weil, Hansen and Patel, 1990, Weil, 1995). With limited time and effort applied to some of these suggested approaches, our experimental results have given us encouragement that we may be on the right track.

One approach makes use of catalysis. In principle, there is no limit to the efficiency of a catalyst. Nature's enzymes show what can be done in catalyzing chemical reactions by many orders of magnitude of velocity. We have suggested that dehydrogenation or oxidative dehydrogenation catalysts should in principle be useful in flame retardancy. A rare example is the finding at GE that parts per million of platinum in some silicone systems provides flame retardancy (discussed in Weil, Hansen and Patel, 1990, *loc. cit.*). In our own laboratory, pursuing a catalyst lead, we found that iron compounds exerted, in proper combinations with other additives, a strong flame retardant effect in some non-halogen systems (Weil and Patel, 1991) As time and manpower permits, we continue to look at this lead further. We observed flame retardant effects, seemingly catalysis of crosslinking, in some rubber blends with small additive amounts of potassium carbonate (Weil and Patel, 1996).

In using catalysts in flame retardancy, there is a dilemma: on one hand, polymers do not penetrate well into the pores of heterogeneous catalysts and char easily deactivates such catalysts, while, on the other hand, many homogeneous catalysts are not thermally stable enough to survive the pre-ignition temperatures. One way out, which has not been much explored, is the use of nano-sized heterogeneous catalysts which have their active sites mainly on the outside surface of the particles rather than in pores.

In classical petrochemical catalysis, combinations of elements are frequently superior. A typical catalyst for dehydrogenation of ethylbenzene to styrene has three or four active oxides in an empirically found optimum combination. We can expect to see similar relationships in the flame retardant catalyst area. This topic has been scarcely explored. In research at Polytechnic, some remarkable examples have been found showing synergism of low levels of certain metal salts with char-forming phosphorus-based intumescent systems (Lewin and Endo, 2000). The new high-throughput methods being researched at NIST could be ideal in searching for effective catalysts. Just as catalyst theory is adding more design and less trial and error to petrochemical catalyst development, in the same way catalyst theory could point to fruitful avenues for flame retardant research.

Turning to a second avenue to much more efficient flame retardants, I propose intensified efforts along the lines of synergism (strong positive interactions) of additives (Weil, 2000). This approach has been tried and proven in the classical halogen systems where antimony oxide combinations are the "workhorses" of the established flame retardant systems. We have been looking for new synergists for phosphorus systems. Some encouraging results have come from combining volatile (vapor-phase active) phosphorus compounds with non-volatile (condensed phase active) phosphorus compounds.

Prof. Lewin at Polytechnic has had some excellent results with a wide range of sulfur compounds as synergists for ammonium polyphosphate in polyester and polyamide thermoplastics (Lewin, 2001). Reviewing our own work and our recent review of the literature (Weil, Lewin and Barinov 2002), we see that sulfur compounds have often been reported and even used in effective combinations with phosphorus for flame and smoke suppression, but no extensive exploration of the mode of action and possible optimization seems to have been done. In view of the low cost and toxicologically favorable character of many sulfur compounds, this looks like a fruitful area for research.

Thirdly, we turn to a solution to the efficient flame retardant problem which is often relegated to the plastics compounder who generally arrives at a workable solution by diligent trial and error. We propose a combination of a mechanism-driven and a data-driven (iterative) solution to building flame retardant systems from multiple components, some synergistic, some just cooperative. The tools for this purpose are surprisingly varied: Even if the polymer must be a commodity polyolefin or styrenic, the potential additive range is broad. We have available the following tools for use in assembling flame retardant systems:

- Materials which could retard ignition, such as non-flammable materials which might bloom to the surface such as fluoro-surfactants, heat-reflective materials, surface antioxidants, surface barrier-formers, and the like.

- Heat sinks of various types in the condensed phase. The "workhorse" materials are alumina trihydrate (ATH) and magnesium hydroxide. Other heat sinks that are used are hydrated zinc borate, hydrotalcite, gypsum and melamine. Some tailored ATH varieties with controlled endothermic regions have been made. Synergism has been sporadically studied, but we think much more could be accomplished. For instance, optimized fitting of the endotherms to the thermal decomposition profile of the polymer by use of a series of such additives could be effective.

• Heat sinks in the vapor phase. This may be a main part of the action of the halogen and melamine systems. Computational approaches show a remarkable relation of heat capacity plus heat of dissociation of flame inhibitors to their efficiency (Larsen, 1980; Ewing, Hughes and Carhart, 1988; Ewing, Beyler and Carhart, 1994).

• Char-forming additives, such as the intumescent types, and there are many ranging from relatively small molecules such as pentaerythritol to oligomers such as novolacs to high polymers such as polyphenylene oxides.

• Silicate barrier forming types. Remarkable efficiency has been shown by some solid polysiloxanes in reducing rate of heat release, probably by barrier formation (Hshieh, 1998), and we have lately found these same siloxanes can contribute strongly in certain self-extinguishing formulations. Nanoclays and their synergistic combinations are promising.

• Char inducing catalysts. The classical material for intumescent systems isr ammonium polyphosphate, which has thermal and hydrolytic stability limitations. Moderate improvement has been made by encapsulation. We have evidence that much more stable materials of this class (for example, phospham and phosphorus oxynitride) are possible (Weil, Patel and Huang, 1993).

• Intumescent systems, which usually comprise a char-forming ("carbonific") component, a char-inducing catalyst, and a blowing agent ("spumific"). In some cases, the main polymer can be the carbonific or the spumific component (Ballistreri, Montaudo, Scamporrino, Puglisi, Vitalini and Cucinella, 1988). The general principals are understood but much experimentation is usually necessary to balance the formulation (Anderson, Dzuik, Mallow and Buckminster, 1985).

• Char-barrier morphology improvers. We have observed that in some non-halogen formulations, iron compounds act as synergists, and our preliminary observations indicate that the char is more coherent. The literature gives further support to the idea that iron, and some other metals such as molybdenum, aid the structuring of carbon.

• Radical scavengers in the condensed phase. One of the several modes of action of red phosphorus is believed to be radical scavenging (Weil, 2000), and some hindered amines may perform similarly.

• Radical scavengers in the flame phase. This is the generally accepted mode of action of hydrogen bromide and antimony halides, and is one of the several modes of action of those phosphorus compounds which can volatilize (Lewin and Weil, 2001).

• Rheology control. There are melt-flow inducers such as peroxides and tetrasubtituted ethanes which act as flame retardant synergists. These additives can help self-extinguishment by dripping, where the flammability standards permit such a mode of extinguishment, or where the drips are non-flaming.

• Drip preventatives such as powdered PTFE. These are useful where melt flow is undesired, particularly where the drips are flaming.

• Char protectants such as some borates and phosphorus compounds, and possibly synergistic phosphorus-nitrogen additives. Inhibition of the combustion of solid carbon permits a char barrier to be maintained, and/or prevents afterglow.

• Ceramic or glassy barrier formers, usually silica- or boron-based, and we have found that delving into commercial glass and glaze technology provides some very useful additives.

I have tried to enumerate in broad classes the many tools which are available for use in flame retardancy. Moreover, there is a strong likelihood of interactions between them, often synergistic, sometimes antagonistic. Therefore, it is very advantageous to use some version of experimental design and statistical data evaluation in the discovery of highly effective systems. We have done this in a number of studies using multivariate regression analysis.

Fourthly, in approaching plastics flame retardancy, we would like to call attention to a powerful approach to flame retardancy which is old with regard to wood and structural protection, but remarkably unexplored in regard to plastics, namely flame retardant intumescent coatings. These coatings, as used to protect wood or sometimes structural steel, pipes, tanks and the like, are able to expand to many times their thickness by forming a foamed char. These char barriers can provide long lived thermal protection and are used, for example, in off-shore oil drilling platforms, refineries and the like. It can be shown by heat transfer measurements that a 27 mm-thick layer of suitable foamed char can protect a substrate from ignition against flame temperatures as high as 1500°C and a 1 cm-thick foamed char can protect up to 4600°C (Weil, Hansen and Patel, 1990, *loc. cit.*). Thinner versions are often used as fire-protective interior paint for wood. Applications of intumescent coatings to plastics are hard to find. One reason is the adhesion problem. With polyolefins, this is a challenging problem for any coating.

The advantage of solving the plastic flammability problem this way is that the interior of the plastic can be optimized for its physical properties, processing characteristics and cost, while the exterior (the coating) can be optimized for fire barrier action. This area has had very little research, mostly just optimization by compounding with a narrow range of ingredients.

In general, flame retardant coatings have hydrophilic ingredients to catalyze and form the char, and this hydrophilicity aggravates the adhesion problem, water resistance and washability. We think this shortcoming is solvable, and there are clues as to how to solve it, for example by building self-intumescent polymer additives, not needing inorganic polyphosphates to catalyze the charring. We also think the relatively under-researched area of phosphorus-nitrogen chemistry will be productive in making available better (more water-resistant) ingredients for intumescent coatings (Weil, Patel and Huang, 1993).

Although in the foregoing discussion, I have tended to emphasize additives, it is important to mention that minor polymer modifications may have a beneficial effect on flame retardancy.

Many of these proposals can be carried out with relatively benign chemistry. By lowering the level of additives, the environmental questions are alleviated. By preventing fire efficiently, the environmental pollution which occurs from fire, such as polycyclic aromatic hydrocarbons in soot, is prevented. It is practically futile to try to make the fire atmosphere breathable, since in the final analysis it seems that CO is the main killer (Hirschler, Debanne, Larsen and Nelson, 1993; Nelson, 2001), but by preventing or slowing down fires, toxic combustion gases are certainly avoided or minimized. There is no credible case of a flame retardant causing any fire casualties, and there is ample evidence that the use of flame retardant chemicals saves lives (Stevens and Mann, 1999).

So far in this paper, I have addressed research needs. Turning to educational needs, we perceive a shortage in this country of people trained in the chemistry and materials side of fire sciences. Regarding flame retardant additives research in the U. S., besides our Polymer Research Institute at Polytechnic, mention should be made of Marquette University (Prof. Charles Wilkie) and Florida Institute of Technology (Prof. Gordon Nelson). Inherently flame retardant polymers and composites are researched at Virginia Polytechnic, and we will hear more about that work from Prof. Riffle. But, altogether, the numbers of students doing graduate research and studying flame retardancy seems small relative to the importance of the problem. Other speakers at this meeting will address a similar situation regarding fire engineers. I think it is fair to say, judging from perusal of the current literature, most of the students doing graduate work in the chemistry and materials science aspect of fire sciences are from overseas, and of course we lose many of these when they return home. Young people at the assistant professor or associate professor level in this area of applied science or related basic science are practically non-existent in this country. In the speaker's judgment, the UK, France, Italy, China, Japan and Russia appear to be training more young people in this area of applied science than is the US.

Some of the barriers to progress in the field of fire-resistant materials are: cost (extremely important in the highly competitive commodity plastics), unfavorable effects on physical properties and processability, lack of compelling regulations to flame retard many kinds of combustible products, inadequate basic research to support and stimulate innovative approaches, increasingly short-term focus in industrial research.

One important, and rather obvious, need for action is to initiate more university research projects in the US on innovative flame retardant additives and coating for plastics. Having some NSF projects in the chemical and material aspects of fire sciences would elevate the attractiveness and productivity of this field. My preference for the main thrust of the research would be to try to make use of catalysis, synergism and intumescence to reach highly efficient flame retardant additive systems for the most important plastics.

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Polymer Matrix Composite Constitutive Properties, Evolution & Their Effects on Flame Durability & Structural Integrity

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Abstract

Fiber-reinforced polymer composite materials (FRP) are gaining acceptance in civil and building infrastructure applications worldwide. Most FRP implementations in building structures are experimental and compliance with fire codes has either not been the focus, or this has been dealt with through application of protective coatings. Recognizing that this is not a long term solution, this paper seeks to summarize the general state of knowledge in the area of FRP composites and their response to fire conditions. With the polymer as the primary concern, there is a clear correlation between the matrix material and the resistance and response to damaging heat flux. Glass transition temperatures for commercially available matrix materials are typically 120-400°C; no match for the higher temperatures observed in realistic fire situations. Fire resistance is designed into these materials through one of two methods: (1) A gas phase mechanism whereby gaseous decomposition products inhibit approach of oxygen to the flame, and (2) Via char formation. In either case the property evolution (reversible and irreversible) is influenced by the loss in stiffness and strength from temperatures which exceed the glass transition temperature, and loss in sections from ablation. Charring of the surface plies and ply delaminations can insulate the composite underneath, thus extending the life. With temperature driving the evolution in properties, spatial knowledge of the incident heat flux, knowledge of property evolution, and the ability to incorporate property evolution to describe structural integrity, are central to simulating structural response of building structures under a fire threat.

Introduction

The recent interest in fiber-reinforced polymer composites (PMC's) for civil infrastructure and building applications has generated a need for a closer look at their performance and stability under fire conditions. Design engineers typically express concerns about the integrity of PMC bridge structures exposed to fire. Walls and columns strengthened with FRP retrofits for seismic considerations have relied on the ASTM equivalents to the Uniform Building Code (UBC) as a qualification for building materials when considering fire. Specifically, the standards for fire resistance (ASTM E119 = UBC 43-1), flame-spread and smoke density (ASTM E 84 = UBC 42-1) and non-combustibility of building materials (ASTM E 136 = UBC 4-1) form the basis for selecting building materials.

As of yet, there are no comprehensive codes, or guidelines for specifying codes, concerning fire resistance and structural integrity. This is with exception to safety provisions in the ACI 440F code which requires a new factored nominal moment larger than 1.2 dead plus 0.85 live load to address structural integrity of bonded repairs [1]. More comprehensive and validated guidelines will be required as routine use of these materials is sought. Such provisions will be introduced as the industry matures and other PMC housing structures are designed and evaluated for routine use. In particular there are several companies moving forward with the development of modular structures fabricated from reinforced polymers [2, 3]. These structures have been enabled through innovative production and joining features that reduce the cost of component manufacturing and construction as compared to the "stick built" homes. "Snap joining" technology, for instance, can be efficiently manufactured and field constructed with integrated features (e.g. panels incorporating snap joining/sealing features, electrical and plumbing traces) that will serve multiple functions (Figure 1).

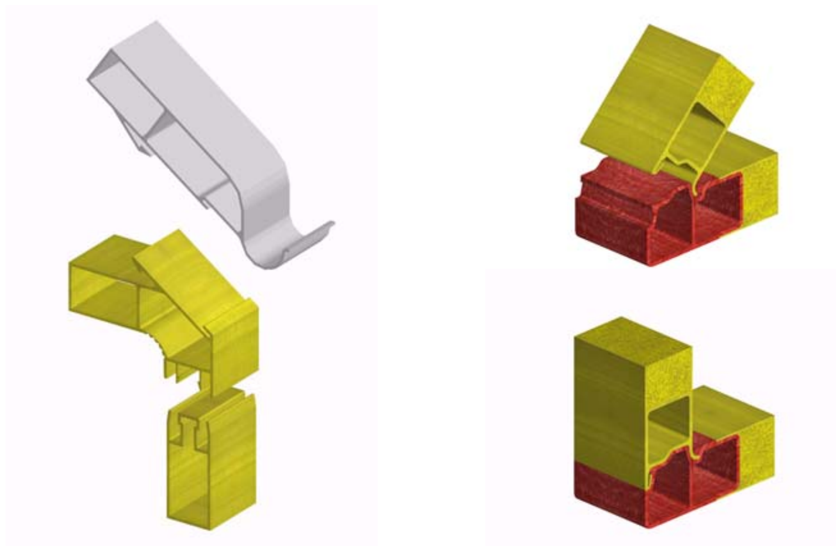

Figure 1. Snap-joining technology: **Left** - wall-ceiling-roof connection with integrated gutter, **Right**– Tilt installed wall-to-floor joint

Flame Properties of Polymer Matrices for Structural Composites in Construction and Infrastructure

Cone calorimetry can provide information on burning rate (indicated by the peak in the heat release rate and the average heat release rate) and char formation [4-7]. While there is limited experience from which to specify PMCs in fire critical areas [7], the performance of various classes of fiber/polymer composites have been studied or at least screened [8, 9]. There are two major mechanisms by which neat polymers are rendered flame retardant: (1) A gas phase mechanism whereby gaseous decomposition products inhibit approach of oxygen to the flame, and (2) Via char formation.

Polymer	Flame Performance	
	Time to Ignition	PHHR
Polytetrafluoroethylene	**No ignition**	**13 kW/m^2**
Poly(vinyl chloride)	**85 sec.**	**183 kW/m^2**
Polystyrene	**97 sec.**	**1101 kW/m^2**
Nylon 6,6	**65 sec.**	**1313 kW/m^2**

Figure 2. Flame properties from cone calorimetry (measured at an incident heat flux of 40 kW/m^2) of halogenated vs. non-halogenated aliphatic polymers [4]. Note the order of magnitude improvement in the peak heat release rates (PHHR) of the halogenated vs. non-halogenated materials.

Halogenated polymers burn relatively slowly due to the gas phase mechanism (Figures 2-3), but such materials do not necessarily form high char yields. One major detraction when considering halogenated materials, however, is that dense smoke usually results upon burning, and in at least several cases, the concentrations of toxic carbon monoxide are unusually high. One can note at least an order of magnitude improvement in burning rates (i.e., lower PHHR) for all of the halogenated polymers vs.

non-halogenated materials. For example, oligomers from tetrabromobisphenol A and epichlorohydrin provide the base materials for commercial flame retardant vinyl esters and epoxies (figure 3). Flame retardant vinyl ester resins are typically blends of brominated with non-brominated oligomers diluted with styrene. Networks from such compositions have relatively slow burning rates but they typically only exhibit about 9 weight percent char (Figure 3) [10]. When brominated epoxies or vinyl esters burn, they also evolve high concentrations of toxic carbon monoxide.

Polymer	Flame Performance			
	Incident Heat Flux	Time to Ignition	PHHR	Char
Polytetrafluoroethylene	**40 kW/m²**	**No ignition**	**13 kW/m²**	
Poly(vinyl chloride)	**40 kW/m²**	**85 sec.**	**183 kW/m²**	
Fluorine-containing PEEK*	**50 kW/m²**	**138 sec.**	**87 kW/m²**	**25%**
Brominated vinyl ester**	**50 kW/m²**	**44 sec.**	**290 kW/m²**	**9%**

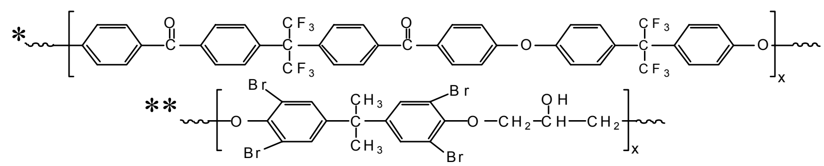

Figure 3. Cone calorimetry results for halogenated polymeric materials illustrating the slow burning rates [4, 11, 12]. There is a need to better understand effects of smoke density and the nature of the by-products.

Polymers with highly aromatic chemical structures in their backbones are flame resistant due to formation of substantial char upon pyrolysis (Figure 4). Polymers with aromatic backbones comprised of "ladder" structures, exemplified by the aromatic polyimides, also exhibit these properties. This is undoubtedly related to the fact that these materials lack thermally labile, aliphatic C-H bonds in the polymer backbones, and are thus inherently more thermally stable. Moreover, the aromatic rings lead to char, which may be important for forming protective surface layers during the pyrolysis process. Quantification of this aspect will require a better understanding of the behavior of these materials during pyrolysis.

Polymer	Flame Performance			
	Incident Heat Flux	Time to Ignition	PHHR	Char
Ultem polyetherimide	**50 kW/m²**	**160 sec.**	**128 kW/m²**	**79%**
Poly(dimethylsiloxane-b-etherimide)	**50 kW/m²**	**97 sec.**	**210 kW/m²**	**32%**
Fluorine-containing PEEK	**50 kW/m²**	**138 sec.**	**87 kW/m²**	**25%**
Polysulfone (UDEL)	**40 kW/m²**		**170 kW/m²**	
	50 kW/m²	**126 sec.**	**431 kW/m²**	**56%**
	70 kW/m²		**310 kW/m²**	

Figure 4. Polymers with all-aromatic backbones are highly resistant to burning and protect their underlying substrates via formation of large amounts of char [4, 13, 14].

Although it is known that aromatic polymers such as those described in figure 4 have good flame retardance, these materials can be expensive, and this detracts from their desirability for composite components in construction and infrastructure. The military and civilian aircraft communities have developed methods to functionalize aromatic polyimides and poly(arylene ether)s with thermally stable, crosslinkable terminal groups (e.g., phenylethynyl functional oligomers) [15-19], which could provide processible, corrosion resistant, flame resistant, PMC matrices. Such materials have not really been considered as construction materials due to their potential costs, but this may be attractive for flame resistant components.

Structural polymer matrix composites are typically comprised of about 60 volume percent fiber and 40 volume percent of the polymer matrix. Fibers utilized in applications requiring flame resistance are limited to carbon and glass, both of which exhibit excellent performance in a fire.

Thermosetting polymer matrix materials suitable for structural applications can be classified in terms of their thermal performance (Table 1), which often parallels their applications (and price). The vinyl ester and unsaturated polyester matrix materials are utilized to produce rapidly manufactured parts for construction and infrastructure. Their free radical curing mechanism and low viscosities make them ideal for pultrusion or low temperature VARTM processing. The resultant networks are highly crosslinked which leads to good environmental and corrosion resistance, and the materials are inexpensive. Unfortunately, unless they are halogenated, they lack flame resistance and residual integrity, and pose a health threat in enclosed spaces. It is clear from the flammability tests that these materials are not the most desirable systems in that regard (Figure 5). Phenolic novolac or resole networks have inherently low flame-spread, slow burning rates, and the materials are cost-effective [20]. They are highly aromatic and also have hindered phenol units along the backbones, which may effectively protect the materials through oxygen scavenging. The viscosities and curing chemistries for undiluted phenolic resins, however, do not allow fabrication of void-free composites by methods typically used for manufacturing construction components (i.e., pultrusion or VARTM). Conventional thermal curing of resole oligomers evolves water and produces voids in the composites which detract from structural properties. One approach to overcome some of these issues is to cure novolac resins with epoxy or even phthalonitrile crosslinking reagents [21-25]. Some of these matrices have excellent structural properties combined with good fire resistance.

Table 1. Thermal performance often dictates the applications for thermosetting polymer matrix systems.

System	T_g (°C)	Current Applications
Vinyl esters – styrene Unsaturated polyesters – styrene Low temperature epoxies Phenolics	Moderate (≈120-160)	Civil engineering (e.g., construction, infrastructure), automotive, ships
Cyanates	High (≈260)	Electronic materials, adhesives and matrices, civilian aircraft
High modulus epoxies	High (≈240)	Military
Functionalized poly(arylene ether)s	High (200-280)	Tougheners, military
Functionalized polyimides Phthalonitriles	Very high (200-400)	Aerospace, electronic

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Resin	Flame Performance			
	Time to Ignition	PHHR	CO/CO_2	Char
Unsaturated polyester-styrene	**53 sec.**	**710 kW/m²**	**0.025**	**13%**
Vinyl ester-styrene	**69 sec.**	**619 kW/m²**	**0.028**	**11%**
Epoxy-DDS		**1230 kW/m²**	**0.04**	**5%**
Phenolic	**272 sec.**	**124 kW/m²**	**0.02**	**54%**
Phenolic Resole		**116 kW/m²**	**0.01**	**65%**
Phenolic-epoxy (65:35 wt:wt)	**75 sec.**	**263 kW/m²**	**0.02**	**26%**
Phenolic-phthalonitrile (85:15 wt:wt)	**102 sec.**	**137 kW/m²**	**0.02**	**54%**
Polysiloxane network	**45 sec.**	**80 kW/m²**	**0.02**	

Figure 5. Flame properties of thermoset polymer matrices for composites measured by cone calorimetry with an incident heat flux of 50 kW/m² [5, 21, 23, 25, 26]. PHHR is peak heat release rate.

Finally, several extremely fire resistant thermosetting resins have been developed and studied by the Navy, including bis-phthalonitriles matrices [27]. These materials must be cured slowly at elevated temperatures, but indeed have extremely good flame properties.

Modeling of Fire Damage Mechanisms in Polymer Matrix Composites

A considerable amount of work has been completed to begin examining materials that do hold promise under conditions of fire, e.g., the phenolic matrices. Mechanics that describe the thermochemical and the resulting mechanical properties have been expanded over the years (first studied by Bumford et al. [28]). This work has motivated examination of fire durability and structural integrity in anisotropic composites [29-35]. Although the community still lacks a complete description of relationships between polymer composition/microstructure and fire behavior [36], some success at combining the thermochemical processes to residual properties of composites has been achieved.

We understand that upon exposure to the flame/heat, the matrix material of the polymer composite first undergoes reversible changes in physical properties (lowering of the elastic modulus by transitioning from the glass to a rubber and thermal expansion). These reversible changes occur in the early stages of a fire and can cause the structure to exceed buckling or deflection-driven limit states. A review of glass transition temperatures for various polymer composites in Table 1 shows that the temperatures at which the greatest change in mechanical properties takes place (i.e. the T_g) can vary by nearly 300°C depending on the polymers and their economics. At higher temperatures (200-300°C) irreversible, multi-stage, decomposition reactions (pyrolysis) occur causing evolution of gases [37] and formation of carbonaceous char, particularly at the surface directly exposed to the heat flux [31]. The process of polymer material evolution and response to intense thermal conditions are summarized in a National Research Council Report [6]: *Thermal degradation, char formation, transport of degradation products, ignition and fire growth.*

The above described phenomena alter the thermal/physical properties of the polymer, and also result in ply ablation, introduction of additional stresses, and reductions in lamina strengths. Delaminations commonly result from combined thermal expansion of the surface lamina due to thermal gradients, and gas evolution between plies of the laminate [33, 34, 38]. As a result of the changes to the laminates, the structures lose stability (reductions in moduli) and undergo reductions in load-carrying capacity (increases in ply stresses and reductions in the ply strengths).

However, some of the damage modes and material changes can be beneficial to the laminate for fire resistance. The formation of char, the char itself, and delaminations within the laminate surface region reduce thermal conductivity and protect the underlying lamina from further damage and exposure to higher temperatures [34]. This self-insulating [39] process leads to a "slow burn-through" process in thick laminates [38]. The factors that influence this process are chemical structure of the matrix material, the nature of added flame retardants, heating rate, ultimate temperature, manufacture-induced flaws/porosity of the virgin material, moisture content, and the initial and evolving thermal conductivity and permeability in the fiber and transverse directions. It is therefore clear that the type of fiber, fiber volume fraction and the quality of the manufacturing process, in addition to the character of the matrix, can affect this evolving thermo-chemical interplay.

Models to describe residual strength

Recent work by Burdette and Reifsnider [40, 41] have attempted to bring together some of these issues to configure an approach that assesses residual strength and predicts structural integrity. A clear concern in making predictions of residual structural performance for composites in intense heat conditions lies in the description of incident heat flux for a given fire condition. The Fire Dynamics Simulator [42] provided the necessary input for subsequent thermal-mechanical modeling. The incident heat flux was used to describe the thermal distribution in a bending-loaded, unidirectional AS-4/polyphenylene sulfide, semi-crystalline polymer composite. Compression strength micromechanics were augmented with a description of polymer stiffness as a function of temperature (20 to 200°C) where the T_g was approximately 90°C. Time-to-failure was subsequently predicted when the bending strain reached the critical compression strain in the fiber of the unidirectional composite. Through this approach, the fire size could be directly related to structural failure given the proximity to the fire and the surrounding boundary conditions. This study demonstrated the importance of relating incident heat flux from a fire state to the temperature distribution in a composite sample. Moreover, knowledge of the temperature distribution within the structure allows for determining failure, given an appropriate failure prediction methodology, purely based on the evolving thermal-mechanical properties of the polymer.

A feature of the degradation and property evolution process of the PMC laminate that may not be fully appreciated involves tracking the heat and the resulting temperature distribution. As pointed out above, temperature controls both reversible and irreversible composite properties. More importantly, temperature distribution is influenced by the local heat flux, both internal and external. If we consider extreme incident heat flux conditions for a jet fuel pool fire, the measured heat flux ranged from 90 to 160 kW/m^2 [6]. Although these values are extreme, they are realistic considering the response of the twin towers to fuel fires. Comparing this range in extreme incident heat flux to cone calorimetry measurements (Table 2) for average heat release (over 300 sec.) for various composites, we find the internal heat generated from burning is equal to or greater than the incident flux [8]. Moreover, if we consider the data of Table 2 relative to its incident heat flux (25, 50, 75 and 100 kW/m^2), in most cases the average heat generated is greater than the incident. One should not overlook, however, that the peak heat release (1200-1300 kW/m^2) is multiples of the incident heat for 10's of seconds, and this could produce considerable irreversible damage to the composite. If this re-irradiated heat is properly included in the estimate of temperatures, the acceleration of property loss and damage will be significant.

This suggests that tracking the internal heat generated is critical to modeling stiffness and strength changes in PMC's that burn. Cone calorimetry data can be used empirically to supply this needed information. Moreover, it also suggests that polymer matrix materials which develop sufficient char upon burning could impart considerably better chances for structural integrity in those composites (as opposed to those composites that have matrices which do not produce significant char).

Table 2. Cone calorimetry peak and average heat release (average over 300 seconds) for various composites material systems relative to the incident heat flux [8].

Composite Material System	*Incident Heat Flux (kW/m^2)*	*Peak Heat Release (kW/m^2)*	*Average Heat Release (kW/m^2) (300 seconds)*	*Average Heat Release/Incident*
Glass/VE, brominated, flame retardant	25	75	29	***1.2***
	50	119	78	***1.7***
	75	139	80	***1.1***
	100	166	-	***-***
Glass/VE, non-flame retardant	25	377	180	***7.2***
	50	-	-	***-***
	75	499	220	***2.9***
	100	557	-	***-***
Glass/Epoxy S2/3501-6, (0/90)	25	39	30	***1.2***
	50	178	98	***1.9***
	75	217	93	***1.2***
	100	232	93	***1.0***
Glass/Epoxy, E-Glass/F155	25	-	-	***-***
	50	40	2	***.24***
	75	246	1	***.01***
	100	232	5	***.02***
Glass/Epoxy, S2/F155	25	20	4	***.2***
	50	93	-	***-***
	75	141	99	***1.3***
	100	202	108	***1.1***
Glass/Epoxy, RTM 9405/9470	25	159	93	***3.7***
	50	294	135	***2.7***
	75	191	121	***1.6***
	100	335	122	***1.2***
Graphite/Epoxy, AS-4/3501-6	25	105	69	***2.8***
	50	171	93	***1.9***
	75	244	147	***1.9***
	100	202	115	***1.2***

Fire Durability and the Development of Design Guidelines

With the goal of developing an understanding of residual performance of a composite structure under fire conditions (while ensuring compliance with smoke and toxicity requirements), the development of design guidelines is in question. While the response of a structure to a specific fire may be considered deterministic, the fire conditions that will cause structural failure are not. Thus, a stochastic approach should be considered where simulation of residual structural performance is estimated for various fire scenarios. In this way, guidelines can be derived that account for variability in fuel load, geometry and flame propagation in a given space. A first step in accomplishing this depends on the ability to integrate various elements of fire simulation, the mechanics of material evolution, and how material property evolution influences the load carrying capacity of a structure given a set of limit states.

Conclusions and Recommendations

Review of presently available literature suggests that the buildings community does not possess the necessary polymer matrix materials to produce fiber-reinforced polymeric materials ultimately suitable for all critical fire applications. The glass transition temperatures of the materials presently under consideration for construction components are low (e.g., vinyl esters and unsaturated polyesters) and these materials do not form significant char upon burning. However, with lower thermal conductivity and the ability to char, FRP structural materials could potentially serve as reasonable reinforcements for repair and retrofit of primary structural elements in building structures. For enclosed spaces, it is also necessary that these materials meet basic smoke and toxicity standards.

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Research Needs For Flammability Of Polymeric Materials

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After a steady decline in the number of civilian fire deaths in homes in the US from 1977 (5865) to 1999 (2895), it appears that the number of deaths remains at around 3000 (the estimated number of the deaths in 2000 was 3420)[1]. In these fires, two classes of items that were first ignited and subsequently caused most civilian deaths are upholstered furniture (average of 658 deaths from 1993 to 1997) and mattresses or bedding (552 deaths)[2]. In order to understand the fire growth processes of upholstered furniture and mattress fires, detailed observation have been made of fire growth behavior on furniture mock-ups using the California Technical Bulletin 133 test protocol[3] and full scale fire growth tests of selected mattresses ignited by a gas burner system simulating burning bedclothes[4]. The tests showed splitting and melting of thermoplastic fabrics, and melt flow of polyurethane foam products to form the complex phenomena of a "basal melt fire". These phenomena significantly affected fire growth and heat release rate of the mock-ups of upholstered furniture. The extensive European study of the fire safety of upholstered furniture also made a related conclusion[5]. When a charring fabric is exposed to fire, it forms a char shell that protects the foam from direct fire exposure, whereas, a melting fabricmelts away to expose the foam to flames. Dripping materials are quite common. It was also observed that flaming melt drips were clear contributors to the spread of flames in the mattress interior, which tended to enhance fire growth and increase heat release rate of the mattress fire. Another example of significant effects of polymer melt flow on fire growth is the flame spread along a thin polypropylene, PP, wall lining. These linings are used in food processing plants, industrial kitchen and similar establishments to prevent work place contamination. It was observed that PP linings in a wall configuration, when subjected to a small ignition source at the bottom, generated a pool-like fire fed by PP melt flow and the pool-like fire controls the growth and spread of fire[6].

The behaviors of polymer melt, melt flow, and dripping have been observed by other studies in addition to those described above studies and their significance on fire growth has been recognized. Despite this recognition, the literature contains only a few systematic studies to understand the mechanisms of these behaviors and to determine their quantitative effects on fire growth[7,8]. Since thermoplastic polymers are widely used in consumer products such as fabrics, electronic devices, automobiles, appliances, and others, in the event of fire, the involvement of thermoplastic materials as a fire growth contributor is highly expected. However, current understanding of the effects of polymer melt flow on fire growth is very limited. Some results from the literature are presented to demonstrate the complex behavior of the polymer melt effects[8]. Figure 1 is a schematic illustration of heat release rate and mass loss rate measurement for a vertically mounted

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thermoplastic polymer sample (5.7 cm wide by 25 cm high by 2.5 cm thick). A small methane fed gas burner was used to initiate ignition across the sample width. Two weighing scales were used to simultaneously measure the sample weight and the accumulated weight of polymer melt drips in the catch pan. Figure 2 shows the results of a commercial PP placed just above a calcium silicate board as the catch pan. As the pool fire grew (see width in the top graph), a self-accelerating process was initiated in which the pool flames enhance the flame growth on the sample face and the rate of polymer melt flow arrival on the catch pan. The pool fire thus boosted its own growth rate and the overall heat release rate from the pool plus sample face fire grew in an accelerating manner. This observation of the dominance of the pool flame over the sample face fire is consistent with that of fire growth over a much larger PP wall lining[6]. Figure 3 shows a plot of the heat release rate versus time for various polymers, using the same experimental configuration. There is a wide variety of behavior influenced by the melt characteristics and the thermo-chemical properties of these polymers. PMMA is the only material that did not yield a melt pool at all because its melt viscosity was so high as to overcome the force of gravity. Nylon 66 was reluctant to burn at all in these experiments, which included no external radiant flux.

The polymer melt flow behavior described above is complex; even the simple two-dimensional configuration described here poses a challenge to model its behavior. The geometry of the problem changes significantly with time. The surface of the melt is a free surface that may undergo considerable deformation, including dripping, and the internal interface between the solid and melted polymer changes its location as the material heats and flows. Unfortunately, there is little modeling of such polymer melt flow except preliminary results of the melting and dripping behavior of the low molecular weight PP in the above experimental configuration under an external radiant flux of 20 kW/m^2 without burning[8]. The study was conducted using the filling capability of the commercial finite-element program FIDAP to model flow processes involving arbitrary changes in shape, including breakup and merging of fluid volumes[9]. The results show the same qualitative behavior of polymer melt flow and dripping as were observed in the experiment. However, the model did not include any thermal degradation of the polymer and thus the polymer melt viscosity was treated as only a function of temperature without including the change in molecular weight.

As described above, the burning mechanism of thermoplastic based consumer products can be very complex but currently fire researchers often characterize flammability properties of polymeric materials (not only thermoplastics but also natural polymers such as wood) with four global parameters. They are material ignition temperature, thermal properties (the value of product of $k\rho c$, where k is thermal conductivity, ρ is density, and c is specific heat), specific heat of combustion, and global heat of gasification. The global heat of gasification is well defined for a liquid and a unique value for each liquid is available in a physical chemistry handbook. However, such value is not well defined for a solid material such as synthetic and natural polymeric materials. Many polymeric materials degrade through complex thermal degradation reaction steps during burning. However, at present it is very difficult to determine the kinetic constants of each chemical reaction of the complex multiple reaction steps.

Additional complexity is inherent in the transport processes, heat and mass transport, in the material. The heat transfer process is probably the easiest to analyze and this could be predicted with a reasonable accuracy. However, the data on thermal properties as a function of temperature up to ignition/burning temperatures of many materials are needed. Although the importance of the transport process of thermal degradation products through wood or charring materials in combustion and biomass research has been demonstrated[10], such a process has been rarely considered or recognized by the fire research community. At present, it is not clear whether the transport process of the products in the form of bubbles through a molten layer of a thermoplastic material has significant effects on gasification (burning) rate of the polymeric material. However, some experimental study[11] and theoretical studies[12,13] indicate its importance. Therefore, fundamental understanding of complex chemical and physical mechanisms in the condensed phase during burning of polymeric materials is severely lacking compared with that in the gas phase. Such understanding is critically needed to develop new flame retardant additives which mainly act in the condensed phase.

At present, it is not clear how much detail of the chemical and physical processes should be included to predict the fire behavior of polymeric materials with reasonable accuracy. Therefore, the term "global heat of gasification" for polymeric materials is the least well characterized among the four parameters described above. All complexities of thermal degradation chemical reactions and of transport processes are lumped into this term. It has been recognized that the validity of a constant global heat of gasification is highly questionable for char-forming polymeric materials such as engineering plastics and natural polymers. Thus, the overall accuracy of a fire growth model depends on the accuracy and validity of a constant global heat of gasification even if it uses a sophisticated gas phase model with high order accuracy. Furthermore, the effects of polymer melt flow on fire growth described above cannot be determined by the four listed parameters. More detailed studies in the condensed phase are needed to determine the important chemical and physical processes which control the gasification rate of polymeric materials. Then we can determine in what detail we need to model the condensed phase processes to be able to predict gasification rate of polymeric materials to comparable accuracy with that of the gas phase.

One important characteristic of the polymer is its molecular weight which has strong effects on polymer melt viscosity and surface tension in turn controling polymer melt flow. Although molecular weight was included for surface pyrolysis of vinyl polymers as early as 1970[14], molecular weight were rarely measured or calculated during the burning of polymeric materials. The change in molecular weight for polymeric materials during burning depends strongly on their degradation mechanisms. A severe reduction in the molecular weight of burning polyethylene occurs due to numerous random scission initiations and extensive melt flow can occur for this polymer. A significant reduction in molecular weight and subsequent melt flow can occur for burning polypropylene and polystyrene. However, polymethylmethacrylate, PMMA, does not significantly reduce its molecular weight during burning due to its dominant depropagation reaction in its degradation mechanism and little melt flow is expected for this polymer. Unfortunately, many systematic flammability studies in the fire research community have been conducted with PMMA in order to avoid the complex melt flow behavior. Since there have been extensive studies of molecular weight modeling[15] and size exclusion chromatography is available to measure molecular weight, it is time that such measurement and modeling of this should be included in the condensed phase study. Without these studies, polymer melt flow effects on fire growth over polymeric materials will not be properly characterized, understood, and modeled.

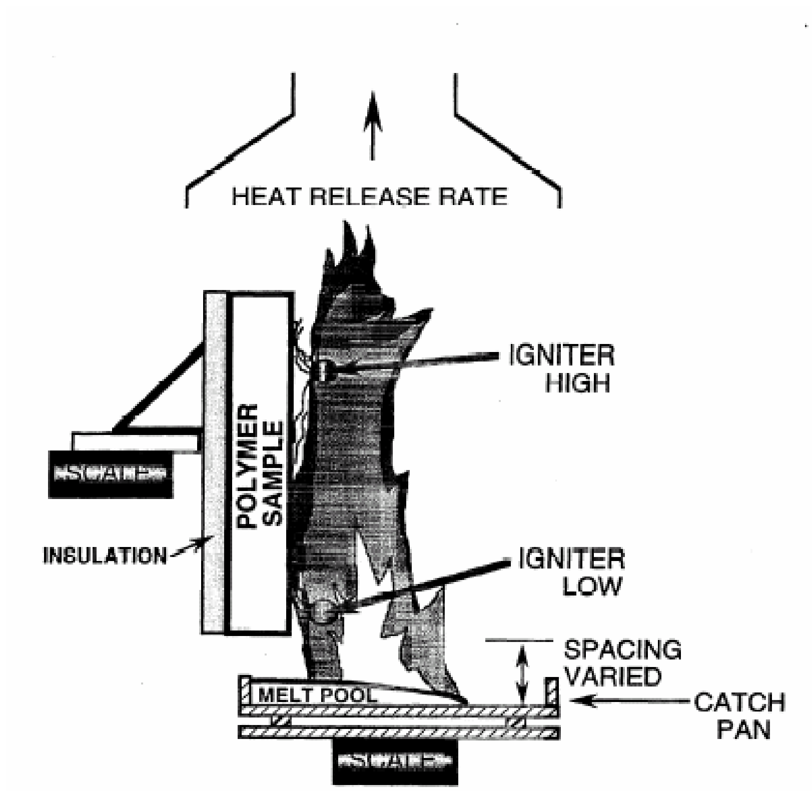

Figure 1. Experimental set-up for polymer melt-drip fire [Ref. 8].

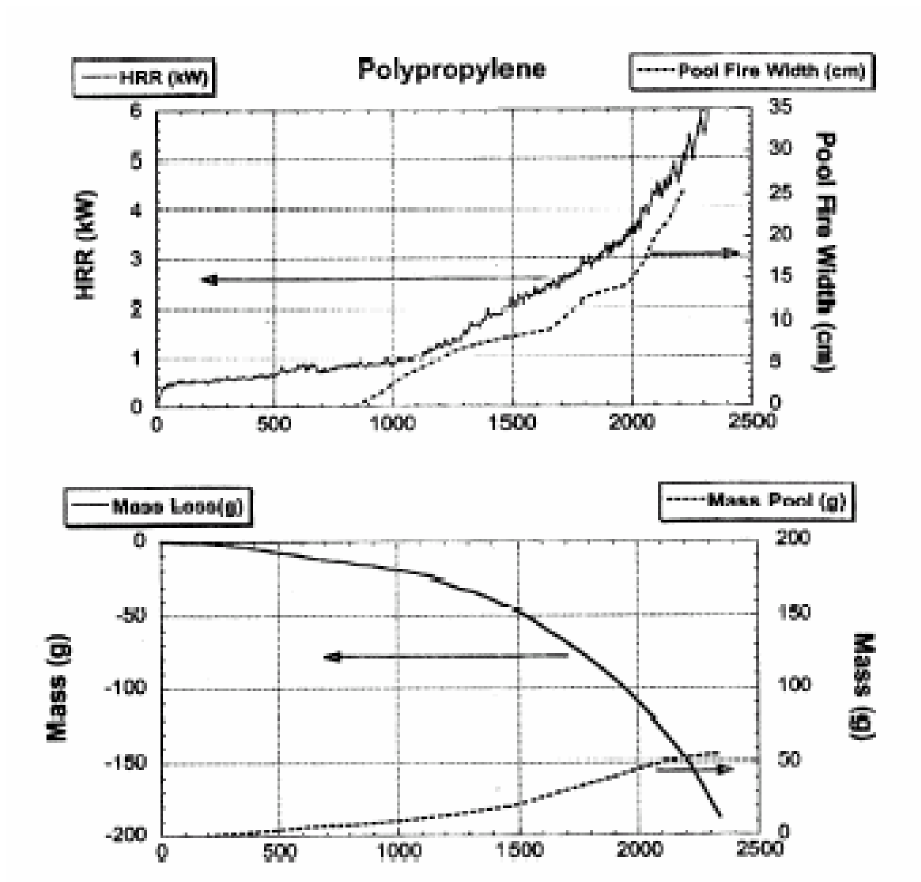

Figure 2. Melt/drip fire behavior of PP, low ignition location, close catch pan spacing [Ref. 8]

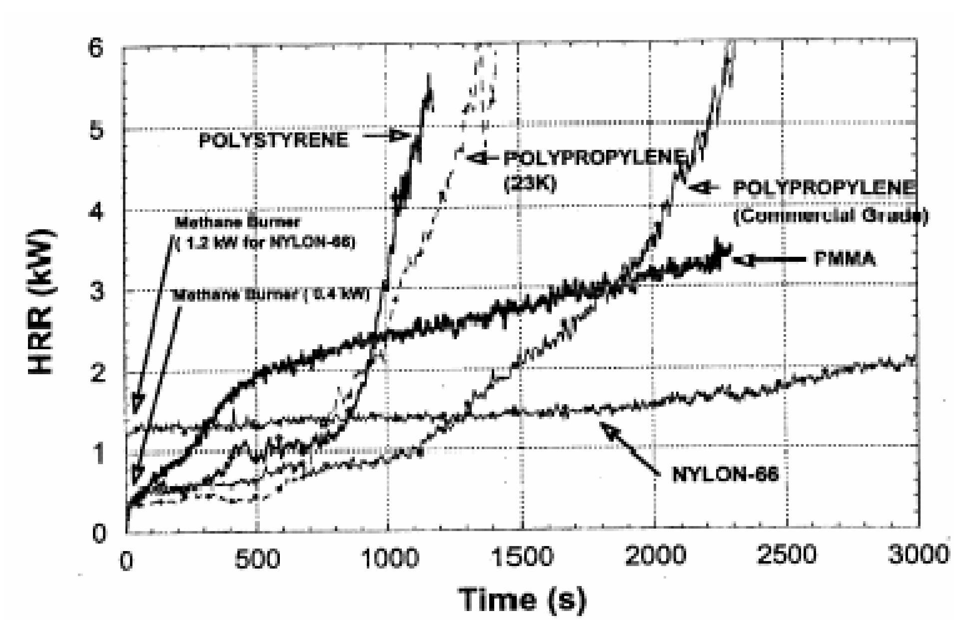

Figure 3. Heat release rate behavior of several thermoplastics, low ignition position, close catch pan spacing [Ref. 8].

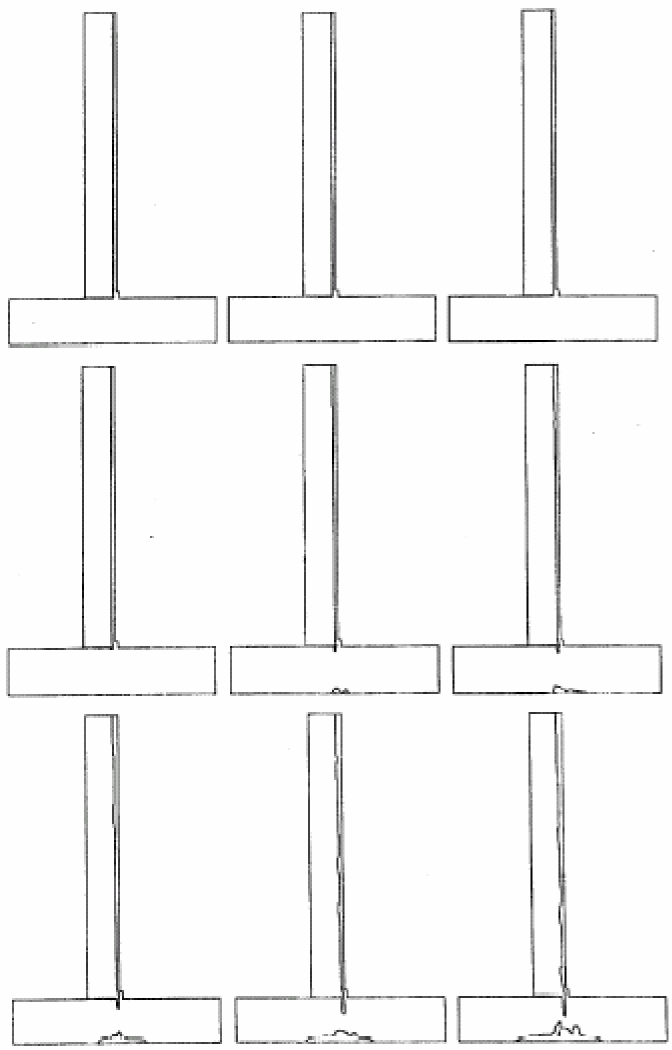

Figure 4. Calculated profiles of low molecular weight PP including dripping into catch basin, from t=20 s to t= 100 s at 10 s intervals without combustion. Incident heat flux on the surface of the vertical PP sample is 20 kW/m^2. [Ref. 8]

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RESEARCH NEEDS FOR ASSESSING THE FIRE SEVERITY IN PERFORMANCE-BASED FIRE RESISTANCE ANALYSES

James A. Milke[1]

Introduction

Fire resistance is a characteristic of a building assembly referring to the ability of the assembly to perform the following two objectives despite exposure to a fire:

- restrict the spread of fire beyond the compartment of fire involvement
- support a load

Restricting fire spread is accomplished by limiting heat transmission to the unexposed side of the barrier and preventing crack development. Heat transmission limits are established to prevent the ignition of combustibles in contact with the unexposed side of the assembly (Schwartz and Lie, 1985). The standard test method, ASTM E119 (2000),[2] expresses heat transmission limits as a maximum increase in temperature on the unexposed side either as 139 °C averaged over the entire surface or 181°C at a single point The ability to support the applied load(s) requires the load-capacity of the structural member to exceed the applied or induced loads and the structural member to maintain its stability. Failure of a load-bearing member may result in local collapse or initiation of progressive collapse.

Typically, fire resistance analyses are performed by conducting a standard test (ASTM, 2000). In the ASTM E119 test standard, the severity of fire exposure is expressed solely in terms of the temperature-time history of the exposure, without reference to the radiative or convective aspects of the exposure. A more recently developed fire resistance test standard, ASTM E1529 (2001), specifies an incident heat flux that is to be applied to the test sample.

The standard test provides a comparative measure of performance and is not intended to predict the response of an assembly exposed to actual fire conditions. Consequently, where an assessment of the expected performance of a building assembly exposed to an actual fire incident is desired, an engineering analysis of the thermal and structural response of the fire-exposed assembly is required. An engineering analysis of the response of fire-exposed structural assemblies involves consideration of:

- fire exposure conditions
- material properties at elevated temperatures of structural members in the assembly
- thermal response of the assembly

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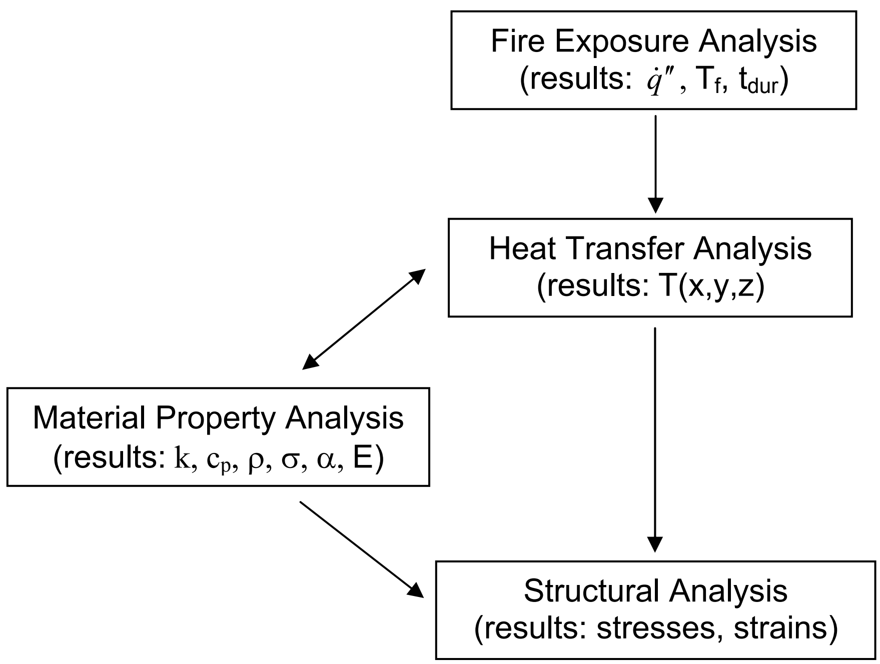
[2] The standard test method is documented in ASTM E119, NFPA 251 and UL 263. For simplicity. the standard test method will be referred to as ASTM E119 throughout this paper.

- structural response of the heated assembly.

The relationship of these four issues in a performance-based design approach for evaluating fire resistance is reflected in Figure 1. The issues are inter-related, *i.e.* a description of the fire exposure provides a description of the boundary conditions for the thermal response analysis and a duration of the proposed fire incident. Results from the thermal response analysis are important for the structural response analysis to determine the temperature rise in the assembly, which affects material properties and results in the development of thermal strains.

Figure 1. Process of Performance-Based Analysis of Fire Resistance



Fire Resistance Analysis Methods

In a recent survey for the American Society of Civil Engineers, Milke and Hill (1997) identified several existing analysis methods to determine the fire resistance of building assemblies. Included in the documentation of these methods is a description of a "natural" fire exposure, i.e. a non-standard exposure as a means of assessing fire severity (Pettersson, *et al.*, 1976)(AISI, 1979)(ECCS, 2001)(ENV 1993, 1995). In these documents, the heat transfer and structural analyses were either described or results provided for a selected group of fire exposures.

Fire Exposure

The fire exposure needs to be characterized in a manner that establishes the boundary conditions for the heat transfer analysis. In addition, the duration of the fire exposure needs to be determined.

In general, acceptable statements of the boundary conditions for heat transfer analyses include either a specified surface temperature or incident heat flux. The incident heat flux can either be explicitly specified or may be implicitly specified by providing the temperature of the exposure and the relevant heat transfer coefficients.

Stipulation of a surface temperature is applicable when the exterior surface temperature of the fire protection material is approximately equal to the exposure temperature, as occurs for steel columns protected with low density insulating materials. This boundary condition is applied in the lumped heat capacity method used to determine the temperature rise in steel columns protected with low density spray-applied protection materials (Lie and Stanzak, 1974).

Another possible boundary condition includes stipulating the exposure temperature in addition to the radiative and convective coefficients associated with the exposure. This statement implicitly describes the incident heat flux on the assembly. An expression for the net heat flux associated with radiative and convective heating conditions is provided in equation (1).

$$\dot{q}'' = F\varepsilon\sigma\left(T^4 - T_s^{\,4}\right) + h_c\left(T - T_s\right) \qquad (1)$$

where:

- F: view factor
- h_c: convection heat transfer coefficient
- $\dot{q}''$: heat flux
- T: temperature of exposing fire/smoke
- T_s: temperature of surface of exposed object
- ε: emissivity of exposure
- σ: Stefan-Boltzmann constant

This approach is used in most heat transfer analyses applied to assess fire resistance (Pettersson, *et al.*, 1976)(Jeanes, 1982)(ECCS, 2001)(ENV 1993, 1995). Consequently, in order to determine the incident heat flux, the analyst needs information on the temperature of the exposure in the vicinity of the building assembly being studied as well as the convection heat transfer coefficient and emissivity of the exposure.

The last means of stipulating the boundary condition is to specify the incident heat flux explicitly. This is commonly applied for cases where radiation is the only mode of heat transfer, such as structural members exposed to radiation from a flame plume from a pool fire. Harmathy's normalized heat load approach is an example of specification of a heat flux (1981). Recent efforts by an SFPE task group involved in developing a design guide to estimate heating conditions for performance-based fire resistance analyses have indicated that a constant heat flux may also be specified as an upper limit to describe the heating conditions associated with fully-developed compartment fires.

Research Needs

Research needs for fire severity are best presented for the specific scenarios considered in fire resistance analyses. Hurley (1999) described three categories of scenarios for fire resistance analyses:

- exposure of interior structural members to fully-developed compartment fires
- exposure of exterior structural members by flame projections from fully-developed compartment fires.
- exposure of structural members to localized, but not fully-developed, fires

Fully-developed Compartment Fires

Traditionally, an expression of fire severity for compartment fires is based on the temperature within the compartment. For example, the Swedish design guide by Pettersson, etal. adopted a set of figures from Magnusson and Thelandersson (1970) that presented temperatures for ventilation-controlled, fully-developed compartment fires as a function of fuel load and ventilation.

For use as a boundary condition, specification of a temperature in the compartment may also require the convection heat transfer coefficient and emissivity. Some guidance is available in the literature on an estimate of the emissivity (Tien, et al., 1995). Often, a value near 1.0 results such that a black body assumption may provide a reasonable estimate of the heating conditions. However, while a value for the convection heat transfer coefficient in the furnace test is suggested (Milke, 1995), little information is available on a reasonable value for the convection heat transfer coefficient in fully-developed compartment fires. Further, unlike the emissivity, a value for the coefficient which provides an estimate of a “most severe” condition does not exist. The lack of guidance on the convection heat transfer coefficient is often dismissed as being unimportant because convection heat transfer is not the dominant mode of heat transfer in fully-developed compartment fires.

The approach by Magnusson and Thelandersson is based on a well-stirred reactor model of the interior environment. The method is applicable to situations where natural ventilation was provided by one or more openings positioned on the same wall of the room.

The well-stirred reactor model assumes that the conditions are uniform throughout the space. Consequently, all structural members in the space are assumed to receive the same thermal insult. Thomas and Bennetts (1999) observed significant variations in the behavior of fires in large spaces or for spaces with high aspect ratios. Neither uniform burning nor uniform temperatures was observed. While the maximum temperatures observed were comparable to predictions using a well-stirred reactor model, the observed duration of the exposure was significantly greater than that predicted using the well-stirred reactor model.

Generally, the duration of the exposure is estimated by the ratio of the fuel load to the mass loss rate. The significant studies of fuel load were conducted several years ago, with the most recent study conducted in the 1970's (Culver, 1976). Fuel composition has changed notably in contemporary office buildings from the initial fuel load survey conducted in the 1940's. Usage of interior spaces has also changed appreciably, especially in the office environment where computers are present at most workstations and desks and chairs are comprised of synthetic materials (and less steel and wood). Large open-office pools of clerical workers have been replaced by open-offices with portable partitions.

In summary, the research needs to assess the fire severity for fully-developed compartment fires include:

- assess the applicability of the well-stirred reactor assumption for spaces
- develop methods to assess the local exposing temperature for those situations where the well-stirred reactor model does not apply
- review applicability of correlations of burning rate for a broad range of fuels
- conduct experiments to study fire development in spaces with openings on multiple walls or from a combination of natural and mechanical ventilation
- confirm the accuracy of fuel load estimates for contemporary buildings from previous surveys especially office buildings where changes in fuel load have intuitively experienced a significant change from the era of the previous surveys
- develop insights for radiative and convective heat transfer coefficients in fully-developed compartment fires.

Exterior Fires

This scenario envisions an exposure of exterior structural members to radiation from flame projections from windows in addition to radiation from internal compartment fires that is emitted through the window opening. Based on work by Law (1978), a design guide has been available for over 20 years to assess the exposure of exterior structural members by flame projections from interior compartment fires (AISI, 1979). Recently, this method was incorporated into the Eurocodes (1995). Law's method requires an estimate of the length of the flame projecting from a ventilation opening based on an empirical correlation. The empirical correlation is based on compartment fires involving wood cribs. The method also considers the estimate of radiation from the flames inside the compartment based on a well-stirred reactor model. In addition, the correlations are based primarily on fires in compartment fires with natural ventilation from a single ventilation opening.

In summary, the research needs to assess the fire severity for exterior fires:

- study flame projections from windows, relative to the dimensions of the compartment, fuel composition, and ventilation characteristics.
- See list for fully-developed compartment fires.

Localized Fires

Localized fires are associated with situations involving a non-fully-developed compartment fire or an exterior fire involving a liquid pool or a storage commodity. An SFPE task group has developed a guide on analyzing the hazard posed by thermal radiation from pool fires (SFPE, 1998). Stipulating the heat transfer boundary condition in this case can be done either by specifying the heat flux emitted from the fire either explicitly or implicitly. A explicit statement of heat flux can be estimated as the product of the radiation fraction and the heat release rate of the fire. The radiation fraction for hydrocarbon pool fires is provided by Mudan and Croce (1995). The implicit statement of heat flux requires that the plume temperature and emissivity are known. Plume temperatures can be estimated from plume centerline temperature correlations (Heskestad, 1995).

In summary, the research needs to assess the fire severity for localized fires include:

- determine the radiation fraction for a broader range of fuel arrays.

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FIRE RESISTANCE RESEARCH NEEDS FOR HIGH PERFORMING MATERIALS

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ABSTRACT

In recent years, there has been a growing interest in the use of high-performing materials (HPM), such as high strength concrete (HSC) and fibre-reinforced polymers (FRP), in civil engineering applications. HPM are often used as structural members in buildings, without fully addressing the fire related issues. At present, there is very little information available on the performance of HPM under fire conditions. Many of the HPM have special characteristics and hence, traditional fire protection measures, as well as conventional fire resistance assessment methods (prescribed in standards), may not be applied to enhance or evaluate their fire resistance. There is an urgent need for the development of fire resistance design guidelines, for the wider application of HPM in buildings and other infrastructure projects where fire resistance requirements are to be satisfied. The research needed for the development of such guidelines include: improved methods for fire resistance assessment; data on material properties (thermal, mechanical, deformation) as a function of temperature; fire resistance experiments on large/full scale structural systems; validated numerical models and parametric studies. The output from this research will be simplified design guidelines that can be incorporated into codes and standards to facilitate integration of fire resistance design with structural design. Undertaking of this research, followed by technology transfer, should lead to wider use of HPM, and result in cost-effective and fire resistant structural systems.

Introduction

Worldwide interest in the use of high-performing materials, such as high strength concrete (HSC), and fibre-reinforced polymers (FRP), in civil engineering applications has increased significantly in recent years. This is mainly due to the advantages, such as high strength and durability (non-corrosive), that HSC and FRP offers over traditional materials, such as normal strength concrete (NSC) and steel (Mufti et al. 1991, Kodur 2000). Further, the costs associated with the use of these HPM in construction have lowered in recent years, thus making them cost-effective in civil engineering projects.

One such HPM is HSC which is widely used in high rise buildings due to the improvements in structural performance, such as strength and durability, as compared to traditional NSC. Generally, NSC structural members exhibit good performance under fire situations. Studies show, however, that the performance of HSC is different from that of NSC and may not exhibit good performance in fire. Further, the spalling of concrete under fire conditions is one of the major concerns due to the low porosity (low water-cement ratio) in HSC. The spalling of concrete (HSC) exposed to fire has been observed under

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laboratory and real fire conditions (Diederichs 1995, Kodur 2000). Spalling, which results in the rapid loss of concrete during a fire, exposes deeper layers of concrete to fire temperatures, thereby increasing the rate of transmission of heat to the inner layers of the member, including to the reinforcement. While many of the design standards for concrete structures have been updated with detailed specifications for the structural design of HSC under normal conditions, there are no guidelines for the fire resistance design of HSC structural members (ACI 1999, CSA 1994).

Another example of HPM is FRP which are used as internal (rebars) or external (wrapping and sheeting) reinforcement in new or exiting (refurbishing) concrete structures because of their high strength, non-corrosive, non-magnetic and light-weight properties. However, preliminary studies indicate that the performance of FRP under fire conditions is well below that of traditional materials. One of the main impediments to using FRP in buildings is the lack of knowledge about the fire resistance of FRP (Kodur and Baingo, 1998).

HPM are being developed to overcome shortcomings in traditional materials and are provided with superior properties under ambient temperatures. This is achieved through significant research activities, funded by organisations such as NSF and CERF, to address the problems related to long term durability and material behaviour of HPM. However, there is not much research, at present, to address fire-related issues of HPM in spite of serious problems with fire performance. Addressing the fire-related issues is critical for the wider application of these HPM in buildings and other infrastructure projects where fire performance requirements are to be satisfied. In this paper the fire resistance research needs for HPM, mainly HSC and FRP, are outlined.

Fire Resistance Requirements

One of the major safety requirements in building design is the provision of appropriate fire resistance to structural members. The basis for this requirement can be attributed to the fact that, when other measures of containing the fire fail, structural integrity is the last line of defence. Fire resistance is the duration during which a structural member (system) exhibits resistance with respect to structural integrity, stability and temperature transmission. Typical fire resistance requirements for specific building elements are specified in building codes (UBC 1995, NBCC 1995).

Fire resistance can play a crucial role in buildings as seen in the collapse of WTC twin towers and surrounding buildings as a result of the September 11 incidents. Many older buildings were generally built with larger cross-sectional areas (required by structural design considerations alone), and with traditional materials, such as concrete and masonry, which enhanced the fire-proofing capacity of the buildings. However, in modern buildings, the use of HPM, together with sophisticated design techniques based on non-linear methods of analysis aimed at optimizing the structural design, often lead to thin structural members, that might result in lower fire resistance characteristics. Hence, there is an urgent need for establishing the fire resistance of structural systems made of HPM.

Fire Resistance of Traditional and High Performing Materials

The fire resistance of conventional materials, such as steel (with appropriate protection) and concrete (NSC), is superior to those of HPM. The fire resistance assessment of these traditional materials is well established and can be made through simplified measures, such as the concept of critical temperature. However, due to inherent properties of HPM, the fire protection and assessment techniques used for traditional materials may not be applied to HPM. This is illustrated by comparing fire resistance assessment and protection techniques for two conventional and two HPM .

Steel Members: When exposed to fully developed fires, fully-loaded unprotected structural steel components attain their critical load-bearing capacity after approximately 15 minutes. Fire protection measures are, therefore, necessary for load-bearing steel structures and is achieved through membrane protection (external insulation) or capacitive protection. The fire resistance of a protected/unprotected structural member is often estimated based on the time required to reach a critical temperature in steel under standard fire exposures.

The membrane mechanism (external insulation) works by delaying the transfer of heat to the steel members. In this method, a fire resistant barrier (insulation) is placed between the potential fire source and the member to be protected. Commonly used insulating materials are: gypsum, pelite, vermiculite fibre, and concrete. Also, intrumescent coatings are often applied in a layer that has the approximate thickness of a coat of paint, to provide the required fire protection.

The method of capacitive protection is based on the principle of using the heat capacity of a protective material to absorb heat. In this case, the supplementing material absorbs the heat as it enters steel and acts as a heat sink. Common examples are: concrete-filled hollow steel columns and water-filled hollow steel columns (Kodur and Lie 1995).

Concrete Members: Concrete (NSC) is less conductive and, therefore, attains higher temperatures at a lower rate than steel. Hence, concrete structural members can often be used unprotected. In reinforced and prestressed concrete structural members, the required fire resistance is generally obtained through the provision of minimum member dimensions and minimum thickness of concrete cover. The minimum concrete cover thickness requirements are to ensure that the temperature in the reinforcement does not reach its critical temperature for the required duration. The critical temperature is defined as the temperature at which the reinforcement loses much of its strength and can no longer support the applied load. For reinforcing steel, the critical temperature is 593°C, while for prestressing steel the critical temperature in 426°C (Lie, 1992). By providing the minimum member dimensions, the unexposed temperatures are kept within the allowable limits for the required fire resistance rating.

If the required fire resistance cannot be achieved with these two provisions, then external insulation, where a fire resistive barrier (insulation) is placed between the potential fire source and the member to be protected, can be used.

HSC Members: The main advantages of using HSC, as a replacement of NSC, are improved durability (corrosion free condition) and strength (thinner structural members).

Hence the current fire resistance criterion for NSC, which is generally obtained through the provision of minimum member dimensions and minimum thickness of concrete cover, may not be applicable to HSC structural systems.

Further, the fire performance of HSC is significantly different from that of NSC due to the occurrence of spalling and faster degradation of mechanical properties at elevated temperature (Phan 1996, Kodur 2000). Spalling results in the rapid loss of concrete during a fire exposing deeper layers of concrete to fire temperatures, thereby increasing the rate of transmission of heat to the reinforcement. The occurrence of spalling limits the use of critical temperature criterion for evaluating fire resistance of HSC structural members. Also, any fire protection techniques for NSC may not be adapted for achieving the required fire resistance ratings of HSC structural members, since spalling will alter the overall response of the system.

FRP reinforced Members: Unlike steel and concrete (NSC), FRP as a material is often combustible and might even alter the fire characteristics. Further, there is wide variation in the composition of FRP (Glass, carbon, aramid) and the orthotropic nature of these materials makes the fire resistance evaluation quite complex and simple fire resistance estimation techniques, such as critical temperature concept, cannot be applied (Gates 1991). Also, commonly used fire protection techniques for concrete and steel may not be adapted for achieving the required ratings of FRP structural members, since there are some major differences, such as combustibility and orthotropic property, associated with FRP as a material (Kodur and Baingo 1999).

Also, in steel-reinforced and prestressed concrete structural members the concrete cover thickness requirements, for the steel reinforcement, are complemented, to a certain extent, by the requirements for corrosion control. For FRP-reinforced concrete structural members, no special concrete cover thickness provisions are required for corrosion control. Furthermore, FRP-reinforced concrete members are often thinner than steel-reinforced structural members, thus the provision of minimum concrete cover to FRP reinforcement to satisfy fire resistance requirements may not be practical or economical (Kodur and Baingo, 1999).

Research Needs

For the effective use of HPM there is an immediate need to develop fire resistance design guidelines for use by the design engineers, architects and regulatory officials. The following research is needed to develop such guidelines.

Fire resistance assessment: There are a number of drawbacks in the current approach of evaluating fire resistance, such as single elemental tests, not accounting for connections and support conditions, and unrealistic definition of failure (basing it on critical temperature of rebars) (ASTM 1988). Hence, the current fire resistance evaluation methods may not be directly applied to HPM due to the complexities (spalling in HSC, burning in FRP) associated with these materials. A new approach should be established and standardised methods be developed, which include evaluating fire resistance based on structural systems and defining failure based on the failure of the overall system (deflection and strength criterion).

Fire growth: The fire growth in the case of structural members made of HPM might be entirely different (as compared to traditional materials) since HPM such as FRP are combustible and alter the fire characteristics, as they act as a fuel source. Hence, for the benefit of design professionals, for use in models and experimental studies, design fire curves should be developed by accounting particular characteristics of HPM.

Computer models: For assessing fire resistance, computer models should be developed, and validated, based on structural systems (not single elements). The models should be flexible enough to allow users to define various scenarios in terms of fire growth, material characteristics (spalling in HSC, burning in FRP) and failure criterion (deflection, strength).

Material properties: For modelling the behaviour of HPM, the effect of heating on the following properties is needed as a function of temperature:

- Thermal properties: thermal conductivity, specific heat, mass loss
- Mechanical properties: tensile strength, compressive strength, modulus of elasticity, ultimate strain
- Deformation properties: thermal expansion, creep
- Transport properties: porosity, pore pressure (for HSC)

Further, many of the HPM (FRP) are combustible and produce off gasses. The toxicity associated with these gasses should also be established.

Experimental studies: To validate the computer models, and to better understand the behaviour of HPM, fire resistance experiments need to be carried out on large/full scale structural systems under realistic fire exposures.

Numerical studies: Using the validated computer models, detailed numerical studies should be carried out to determine the extent of influence of different parameters, such as the concrete cover, on the fire performance of structural systems made of HPM. Data generated from such studies could be used to develop simplified design recommendations, including any additional fire protection measures, for achieving fire resistant systems.

Fire-proofing materials: Since many of the HPM have poor fire resistance characteristics, innovative solutions need to be developed for enhancing their fire resistance properties. This can be achieved either by developing innovative solutions, such as modifying tie configuration and adding fibers to HSC (Kodur 2000, Kodur et al 2002), or by developing innovative fire-proofing materials. Such fire proofing materials should be thoroughly checked for durability characteristics (adhesion, cohesion).

Technology transfer: The above research should lead to: new test methods for evaluating fire resistance; validated computer models for predicting fire resistance performance; innovative fire-proofing materials, fire resistance design guidelines and highly trained professionals. The simplified design guidelines have to be incorporated into codes and standards for design of structural systems.

The technology transfer can be modelled on the same line as that of changes that were implemented into building codes and standards following the San Fernando earthquake in 1971. This should be followed by appropriate training, though seminars, courses etc. of material and structural engineers in fire related design issues. The availability of such guidelines in codes and standards, and trained personnel, will facilitate integration of fire resistance design with structural design. This will lead to wider use of the HPM in buildings and infrastructure projects and result in cost-effective and fire resistant structural systems.

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PERFORMANCE-BASED STRUCTURAL ANALYSIS TO DETERMINE FIREPROOFING REQUIREMENTS: METHODOLOGY, CASE STUDIES, AND RESEARCH NEEDS

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ABSTRACT

A performance-based approach to designing structures for fire resistance is gradually gaining favor as an alternative to traditional prescriptive requirements such as hourly ratings and tables of required fireproofing thicknesses. A performance-based code permits engineers to use thermal and structural analysis to predict the performance of a building during the types of fires it could actually be exposed to rather than a code-specified standard fire. In the USA, performance-based codes have been used for many years in seismic design and other areas of structural engineering, and in the next few years will also be enacted for fire protection design. The methodology for performing these fire analyses is well established and is summarized here. In addition, some typical case studies taken from engineering practice are presented. To make these performance-based methods more accessible and acceptable to practicing engineers and building officials, further research is needed, particularly in identifying high-temperature material properties, codifying approved analytical methods, developing and verifying software, and training engineers in the use of these methods.

Introduction

The basic concept underlying performance-based fire analysis is that a building should be designed for the fire severity that might actually occur in the building rather than for a code-specified "one-size-fits-all" fire such as ASTM E-119. Using factors such as fuel load and ventilation, the maximum credible fire in different locations in the building is calculated and the structural response to these fires is calculated. The key elements of the performance-based approach are:

- Perform a Fire Hazards Analysis to identify all potential fire scenarios and determine the impact of each scenario on adjacent structural members, particularly the fire gas temperatures each member would be exposed to. This involves conducting fire combustion analysis to predict site-specific fire curves (temperature vs. time) and the spatial distribution of these fire curves.

- Evaluate the response of the structural members to the imposed fire hazards assuming varying levels of fireproofing. This involves a Fire Thermal Analysis to calculate temperature history in each member and a Fire Structural Analysis to determine forces and stresses in each member and

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whether local or progressive structural collapse would occur during any of the fire hazard scenarios.

- Where required, develop a risk mitigation plan or revised fireproofing scheme to ensure that performance of the structural system is acceptable for the type of building being designed.

Fire Hazards Analysis

The first step in evaluating a building's response to fire and resulting fireproofing requirements is to perform a Fire Hazards Analysis. All significant individual fire hazards are identified and the resulting fire exposure to surrounding structural elements determined. In line with the general intent of fire codes, the exposure is conservatively developed without taking credit for suppression systems, such as sprinklers. Hazards are worst case credible fires resulting from both fixed and transient sources. A transient hazard could result from trucks or refuse containers that could move about a building. The fire hazards analysis method comprises the following steps:

- Definition of fire areas or compartments to establish how far a fire could potentially propagate within the structure and how much of the structure could possibly be impacted by the fire.
- Identification of potential fire hazards and ignition sources within each fire area. These could be from ordinary building contents, fuel tanks, or possible terrorist attacks or arson.
- Definition of potential fire scenarios (sequence of fire ignition, propagation to adjacent combustibles, and the intensity of the resulting fire).
- Calculation of the resulting exposure temperatures as a function of time for structural members in the vicinity of the postulated fires.

Characterizing a fire scenario requires defining the amount of material involved in the fire, the intensity of burning, and the location of the fire and its plume with respect to targets (structural members). The burning characteristics of materials involved in the scenarios can be derived from published data from the Society of Fire Protection Engineers and a variety of other sources and are based on conservative interpretation of fire test data for actual combustion materials. For each scenario these calculations result in a time-temperature curve for the hot gases in the fire. Also calculated will be how fire temperatures decrease at varying distances from the center of the fire if flashover does not occur. These fire curves serve as input for the next phase of analysis, predicting temperatures in the structural members.

Fire Thermal Analysis

Structural members exposed to hot gases from fires gradually heat up and can reach very high temperatures. The temperature rise always lags the fire temperature because of the thermal inertia inherent in the material and the tendency for heat to flow to cooler material adjacent to the heated area. Fireproofing or other forms of insulation, of course, can greatly slow the temperature rise in protected steel. When the fire starts to cool, the temperature drop in a structural member will lag the falling gas temperature, again because of thermal inertia and fireproofing.

Basic heat conduction theory can predict temperature history in fire-exposed structures when thermal material properties of concrete, steel and insulation are known. The heat conduction field equation for a three-dimensional steel member is:

$$\rho C \ \partial T / \partial t \ + \ K \nabla^2 T = Q \qquad (1)$$

where

ρ	=	density of steel
C	=	specific heat capacity of steel
T	=	temperature distribution in member
t	=	time
K	=	heat conductivity of steel
Q	=	heat input into member
$\nabla^2 (\,)$	=	$\frac{\partial^2 (\,)}{\partial x^2} + \frac{\partial^2 (\,)}{\partial y^2} + \frac{\partial^2 (\,)}{\partial z^2}$

In a fire, the heat input is due to a combination of convection and radiation into the fire-exposed surfaces. This heat flow can be calculated using the equation:

$$Q = A\,[C\,(T_f - T_s)^N + V * \sigma\,(\alpha \varepsilon_f \theta^4{}_f - \varepsilon_s \theta^4{}_s)] \qquad (2)$$

where

A	=	surface exposed to fire
C	=	convection coefficient
N	=	convection power factor
V	=	radiation view factor
σ	=	Stefan-Boltzmann constant
α	=	absorption of surface
ε_f	=	emissivity of the flame associated with fire
θ_f	=	absolute temperature of fire (°R)
ε_s	=	surface emissivity
θ_s	=	absolute temperature of surface (°R)
T_f	=	fire exposure temperature
T_s	=	surface temperature

There are a number of finite element computer codes that solve the heat conduction field equation with this fire boundary condition. The code most commonly used is FIRES-T3 (Iding 1977). All of these codes discretize the field equations into a set of linear equations expressed by the matrix relationship.

$$[C]\{\dot{T}\} + [K]\{T\} = \{Q\} \tag{3}$$

where

[C]	=	Capacity matrix (temperature-dependent)
[K]	=	Conductivity matrix (temperature-dependent)
{Q}	=	External heat flow vector (depends on exothermic reactions and fire boundary conditions)
{T}	=	Temperature vector (time-dependent)

The FIRES-T3 code uses an iterative approach to account for the nonlinearities in the fire boundary condition in Equation 2.

All thermal analyses start with discretizing the structural members into finite elements and defining boundary conditions, both fire-exposure boundaries and other boundaries where heat may escape from the member into adjoining parts of the structure or into the environment. The thermal material properties are defined for all components of the model and the time-dependent fire curve (gas temperature T_f) from the particular fire scenario to be considered is specified. The equations are then solved to obtain the temperature history in all parts of the structural member during the fire. Such temperatures form the basis for a structural analysis of each member and the structure as a whole.

Fire Structural Analysis

Once the maximum temperature loading in each structural member is known, calculations to determine the structural response of these members to the fire can be made, particularly to determine whether any member will fail during the fire. Standard structural analysis methods and computer codes can be used, but they must take into account the special characteristics of materials at high temperatures:

- Thermal expansion (coefficient of expansion multiplied by temperature change), which can be very large in a fire. When there is restraint acting very large stresses can be generated by this thermal expansion, leading to buckling or crushing.
- Effect of temperature on material properties, such as modulus of elasticity and yield strength. When steel becomes hot enough the yield point can drop so much that the member cannot support the loads on it during the fire and collapse will occur. The degradation of yield strength with temperature for A36 mild steel is shown in Figure 5. It can be seen that between 1000°F and 1100°F, the yield point has fallen to only 60% of its room-temperature value. Typical maximum design loads produce about 60% of yield stress, so collapse of a fully loaded member could occur once this temperature is reached, although most steel structures would be much more lightly loaded during a fire and would fail at higher temperatures.

- High-temperature steel creep. Increase in deflection in a flowing manner when loads are not increased is called creep. Steel does not creep at normal temperatures, but when the material reaches 1100°F-1300°F creep becomes important.
- Nonlinear behavior. Structural response during a severe fire can quickly lead to high stresses, yielding, creep and local or general failure. A complete analysis must take these nonlinear effects into account.

Several computer programs were specifically designed to model these special high-temperature phenomena, including FIRES-RC II (Iding 1977) and FASBUS II (Iding 1987 and 1990). General purpose linear programs can sometimes also be used, particularly if steel temperatures are not very high or if there is little restraint to thermal expansion.

Simplified approaches are also possible. For example, in relatively unrestrained steel members, a temperature threshold can be set (typically 800°F-1000°F) at which the yield point is well above the stresses the member must carry during the fire and the member can be considered acceptable. This is the type of acceptance criterion used in ASTM E-119 furnace tests when assemblies are not loaded during the test.

Case Study Number 1 - Transient Trash Fire in Power Plant

The subject of this case study is a steel braced-frame power plant located in Healy, Alaska. The entire power house enclosure can be considered one very large fire compartment, with the exception of the plant administrative and control area separated from the rest of the enclosure by rated fire-resistive occupancy separation walls and doors. The steel-framed enclosure is as high as a 20-story office building. However, its behavior in a fire will be very different since only its lower portions can be impacted by any possible fire. The upper reaches of both the interior and exterior of the frame are not close to combustible materials. In addition, the space inside the enclosure is so large that flashover and other characteristics of compartment fires cannot occur. Therefore, prescriptive code requirements for fireproofing, which are based on the ASTM E-119 compartment fire, are not well suited for designing the fire protection for most of this structure. A performance-based approach which looks at the actual fire exposures this building could be subjected to can give a more rational and economic design.

There are a very large number of both fixed and transient fire hazards to be considered in this plant and much calculation was necessary to determine the effects of each one on the structural steel frame. Some examples of these hazards are shown in Figures 1 through 4 (Lee 1996). To demonstrate the performance-based analysis procedure, one typical fire hazard will be studied here in some detail.

The fire hazard to be examined is a transient trash or refuse fire. Such a fire can occur when transient combustible materials come into contact with ignition sources such as hot surfaces, portable heaters, hot slag from welding and cutting operations, or carelessly discarded cigarettes. A pile of refuse could accumulate wherever there is a floor or grating to support the transient material. Therefore, this is an important scenario to consider since there are many places in the structure which could be impacted by a fire of this type. If the refuse is placed directly against an unfireproofed steel column, and the fire were large enough, the structural integrity of that column might be affected.

The first step in the analysis is to conservatively estimate the quantity of transient material that could be adjacent to a column. The fuel package selected is typical maintenance refuse composed of a cardboard box, Kimwipes, acetone, and a plastic wash bottle. The burning characteristics of this fuel package (about 110 Btu/sec heat release rate) were calculated, from which the gas temperatures of the fire plume impacting the surface of the column were also calculated (Lee 1996), as shown in Figure 6. Note that for this fuel load the fire duration is about 13 minutes and the peak plume temperature is 1600°F. Also note in Figure 6 that the temperature of the gas enveloping the column decreases at higher elevations above the fire, so that only the first few feet of column above the refuse pile are exposed to very high temperatures.

The next step in the analysis is to determine the temperature rise in the steel column itself during the trash fire. A three-dimensional heat conduction analysis using FIRES-T3 is performed for a typical bare, unfireproofed W14 x 90 column, which is the smallest size column in the steel frame and, therefore, would be most severely affected by the trash fire. Also modeled is the base plate and adjacent concrete slab. Note that a fully three-dimensional thermal analysis is necessary here because heat transfer along the length of the column must be considered as well as convective losses from the steel to the surrounding air. Such three-dimensional analysis produces much more accurate results when only a localized area is exposed to fire heat input. In this case, it is assumed that the trash is piled at ground level against one side of the column's web and adjacent flanges, thereby exposing these surfaces to the full radiation from the fire, as expressed in Equation 2. The finite element model is shown in Figure 7 and makes use of the symmetry of the fire and associated heat flow.

Calculated temperatures within the hottest cross-section of the column (about 18 inches from the floor) are plotted in Figure 8. Maximum steel surface temperature of 900°F is reached after 13 minutes of fire exposure, after which the fire begins to cool. Average temperature within the hottest steel cross-section peaks at 715°F, also at 13 minutes of fire exposure.

The final step in the analysis is a structural evaluation of the ability of the steel column to support superposed load when subjected to these temperatures. In this case, temperatures are so low that complex nonlinear failure analysis is not needed. At 715°F, the A36 steel columns retain more than 90% of their room-temperature yield strength (Figure 5), so there can be no significant weakening of the frame from this fire scenario. In addition, the configuration of this frame and its connections will not offer much restraint to the thermal expansion in the columns and thermal stresses would not be important. Therefore, these columns will continue to support full design loading demands at these steel temperatures.

The fire hazard analysis for a typical transient trash fire shows that such fires are too small to significantly affect the load bearing capacity of columns anywhere in the steel frame, even if they are unfireproofed. Therefore, spray-on fireproofing is not necessary for this fire hazard.

Case Study Number 2 - Fireproofing Requirements for the Eiffel Tower II

The Eiffel Tower II in Las Vegas, Nevada, as shown in Figure 9, is a half-scale replica of the original Eiffel Tower in Paris. The primary structure is comprised of steel tubular members which were originally intended to be left bare with no spray-on fireproofing, as was the case on the original Eiffel Tower. However, early in the design process questions were raised about fire safety and compliance with prescriptive building codes. Since this structure was completely unlike typical steel high-rise buildings and would not be subjected to the type of fire envisioned in the code, it was a perfect candidate for performance-based analysis.

Working with the local building officials, credible fire scenarios were postulated, including several based on possible terrorist attack and arson. Following the methodology discussed earlier, fire time-temperature curves were developed for each of these scenarios and affected steel members identified. Since members were relatively light and unfireproofed, thermal analysis was not necessary because steel temperatures would closely follow fire gas temperatures with minimal thermal lag. Maximum steel temperatures in affected members for four different fire scenarios are shown in Figure 10, including a truck fire at the base of one leg and a contents fire in the casino or elevated restaurant. Structural analyses were conducted using the same computer model developed for the general design of the tower by inputting thermal expansion and taking into account loss of steel strength at elevated temperature. An iterative process was followed, conservatively removing or softening members as they buckled, yielded, or fractured. If a stable equilibrium taking into account removed or compromised members could be found, then one could be confident that the tower would not go into progressive collapse from the fire scenario and damage would be localized. This iterative approach was used because a fully nonlinear analyses using one of the specialized fire computer programs was not economically feasible for a structure of this size. After examining all the fire scenarios it was decided that portions of the structure near ground level and above the restaurant and casino areas needed fireproofing and that these areas should be protected by intumescent paint. The majority of the tower would not be adversely affected by fire and was left unfireproofed.

Recommendations for Research

Performance-based fire codes and associated analysis will not find universal acceptance as easily as seismic analysis has. Earthquake structural analysis arose unrestrained by previous practice. Buildings had essentially not been designed specifically for earthquakes, and engineers, architects and building officials gratefully adopted the new methods as they found their way into engineering literature and the building codes. Performance-based fire analysis, however, finds the field already occupied by a long established prescriptive code based on a hundred years of furnace tests and engineering practice backed by a huge industry. The new methods must be highly developed and extensively verified before they can supplement or replace the traditional methods. The following types of efforts would aid in this process:

- Better identification of material properties at elevated temperatures, particularly those of spray-on fireproofing and intumescent paint.
- Research on the performance of structural connections in fires and the development of analytical tools to evaluate such connections.
- Development of peer review protocol for the transitional period when performance-based analysis is first being presented to building officials.
- Incorporation into commercial computer codes the basic capabilities to conduct fire analysis, especially as nonlinear programs come into greater use. This is necessary if fire is to be treated as an additional load case that must be considered in building design.
- More exposure of engineering students and practitioners to the basics of structural fire performance and analytical methods to predict it. Sponsorship of workshops and seminars for non-specialists.
- Some sort of codification of methods to calculate fire curves for the most common fire scenarios so design engineers do not have to engage a specialist for routine structural design.
- More emphasis on examining the fire safety of a building as a whole. Current practice is to consider the fire safety of individual building elements (floor assemblies, columns, etc.) without considering how the fire response of each assembly affects the rest of the building. Research is needed to develop practical methods to avoid progressive collapse in a severe fire and incorporate them into future performance-based codes.

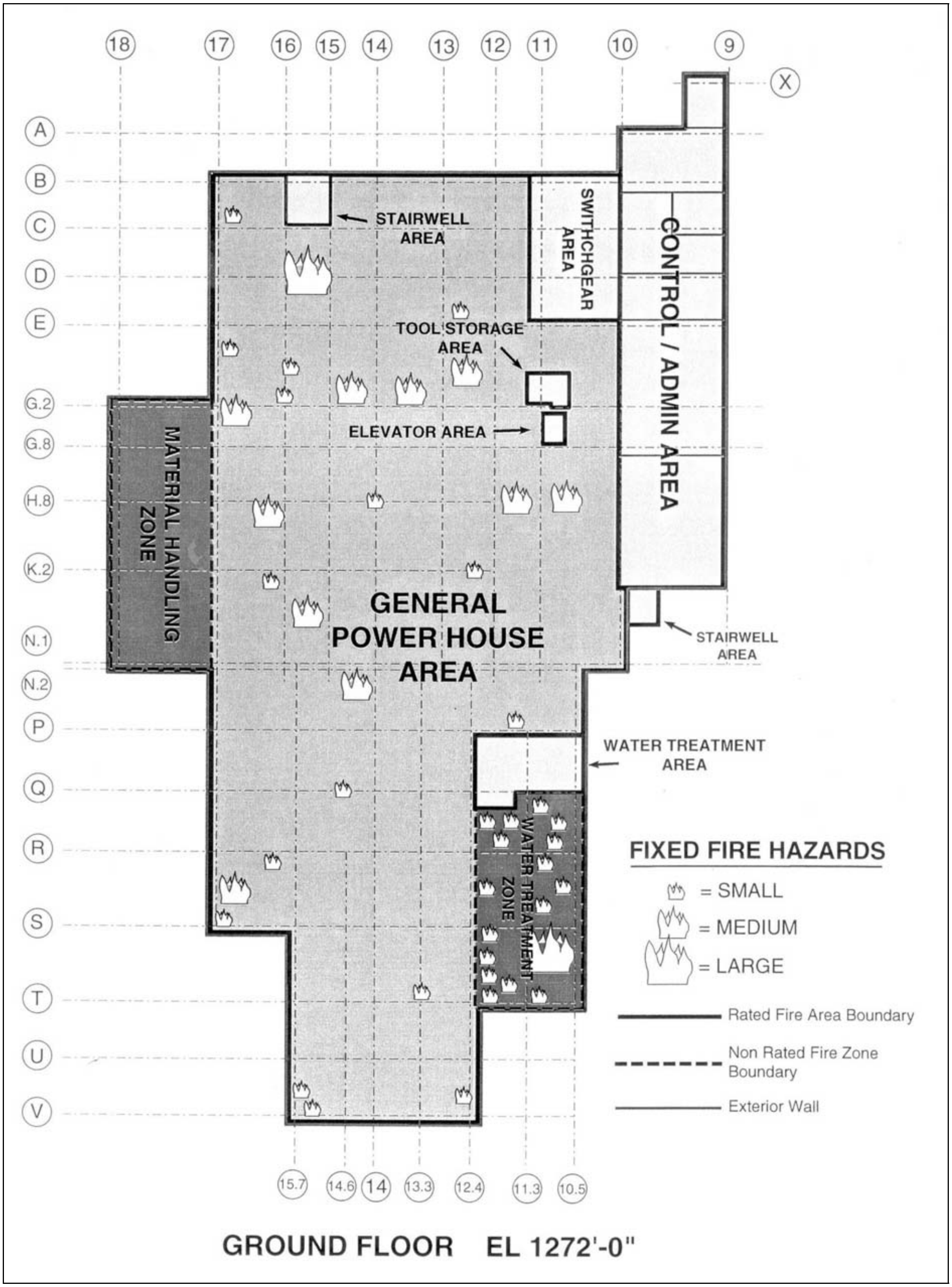

Figure 1. Fixed Fire Hazards on Ground Floor of Healy Power Plant.

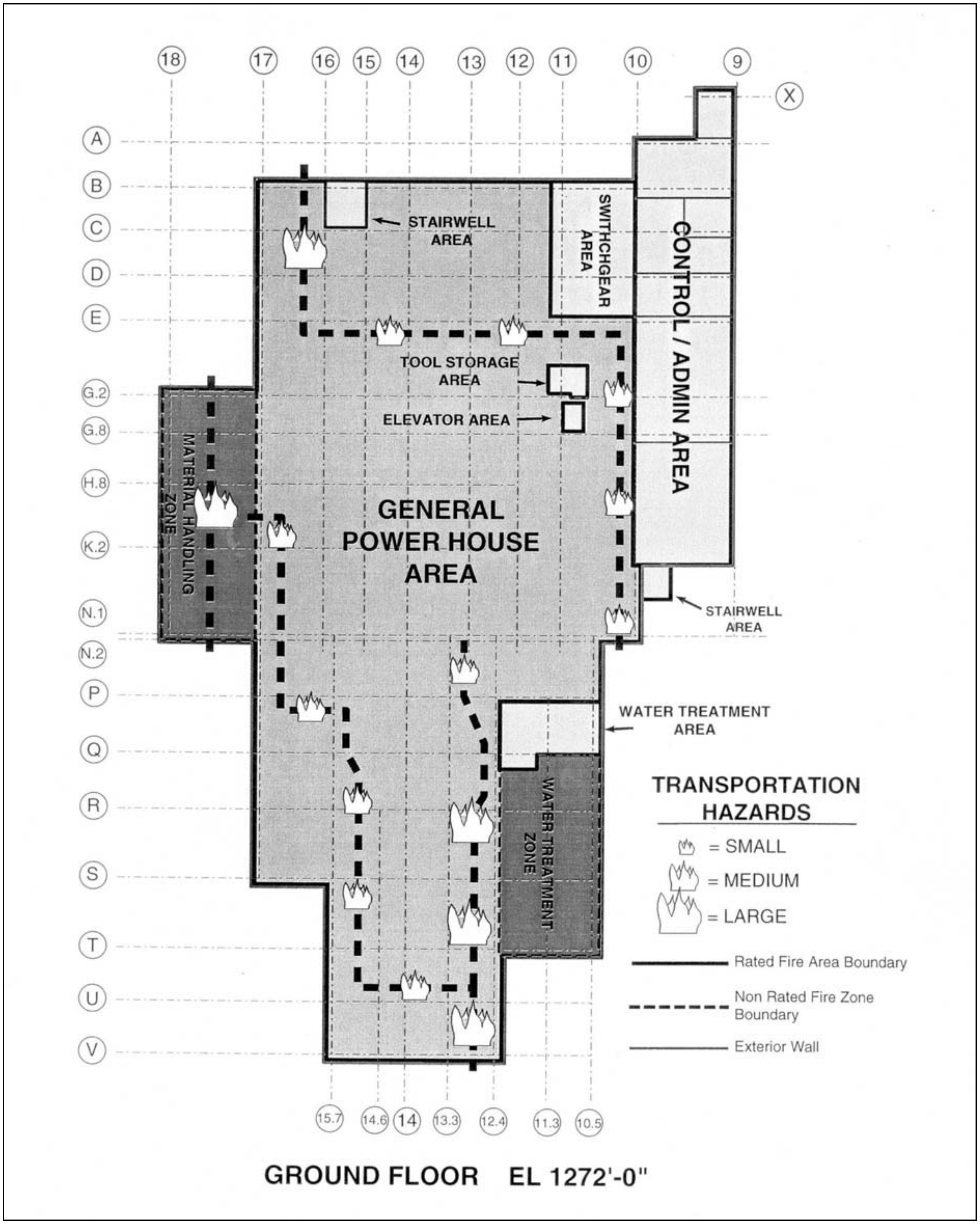

Figure 2. Transportation Fire Hazards on Ground Floor of Healy Power Plant.

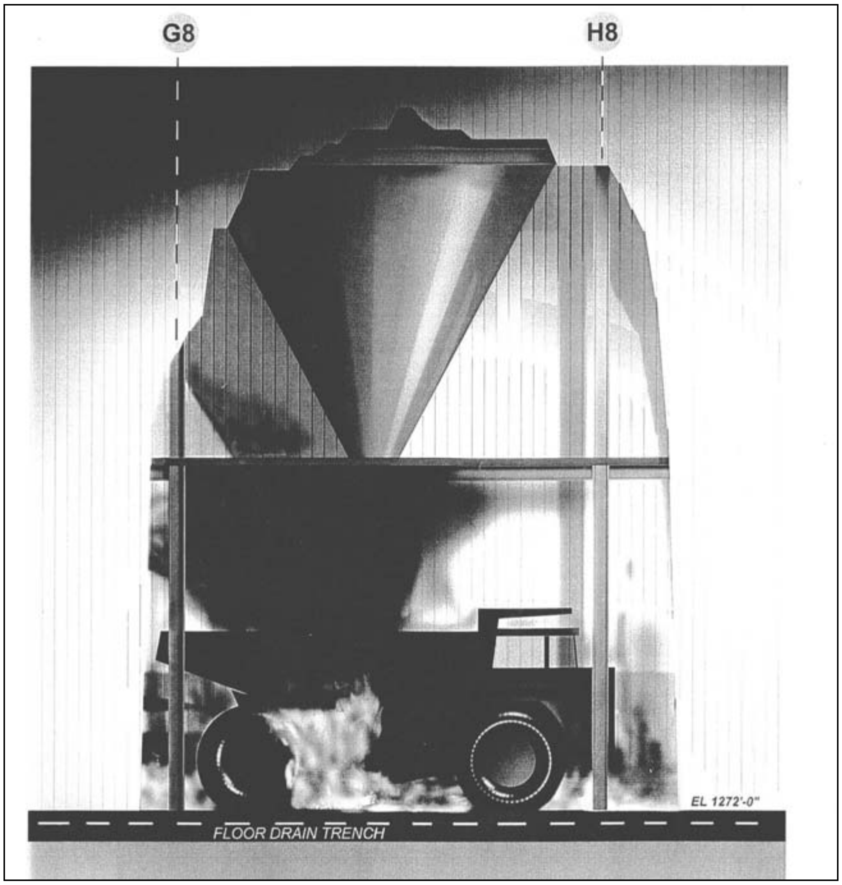

Figure 3. Large Truck Fire Scenario.

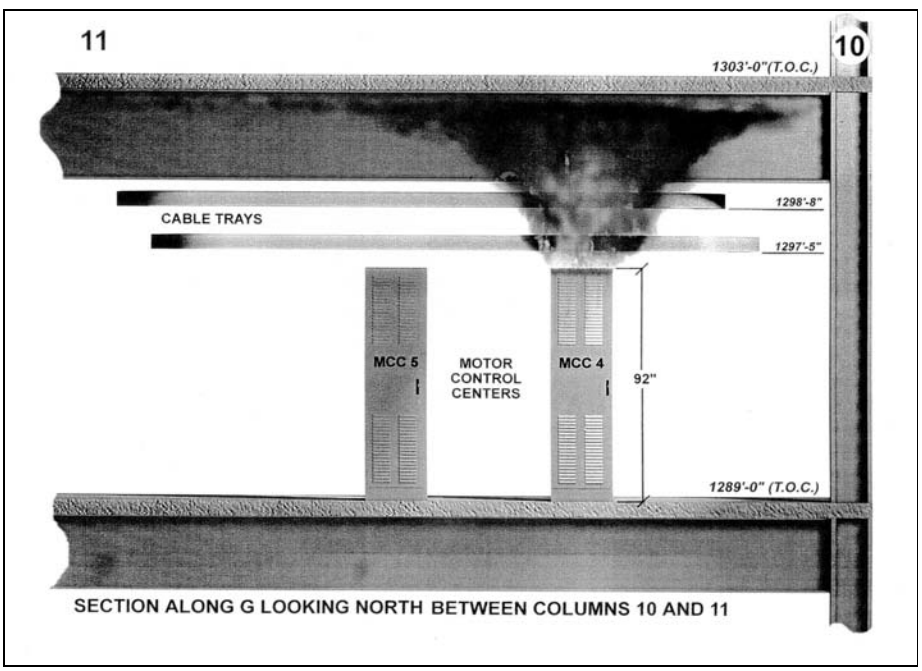

Figure 4. Motor Control Center Fire Scenario.

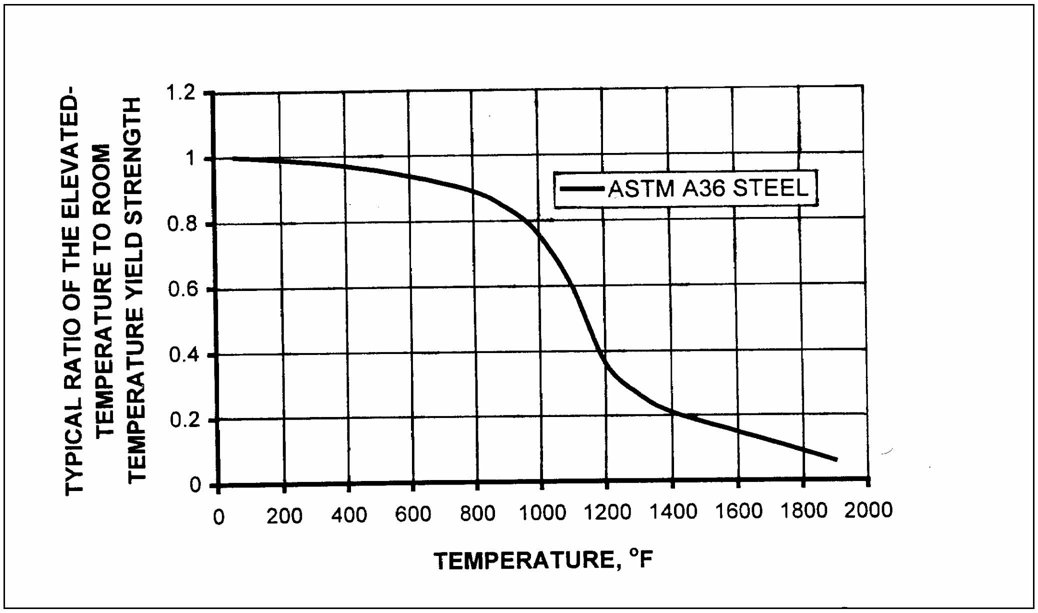

Figure 5. Effect of Temperature on the Ratio Between Elevated-Temperature and Room-Temperature Yield Strength of Steel.

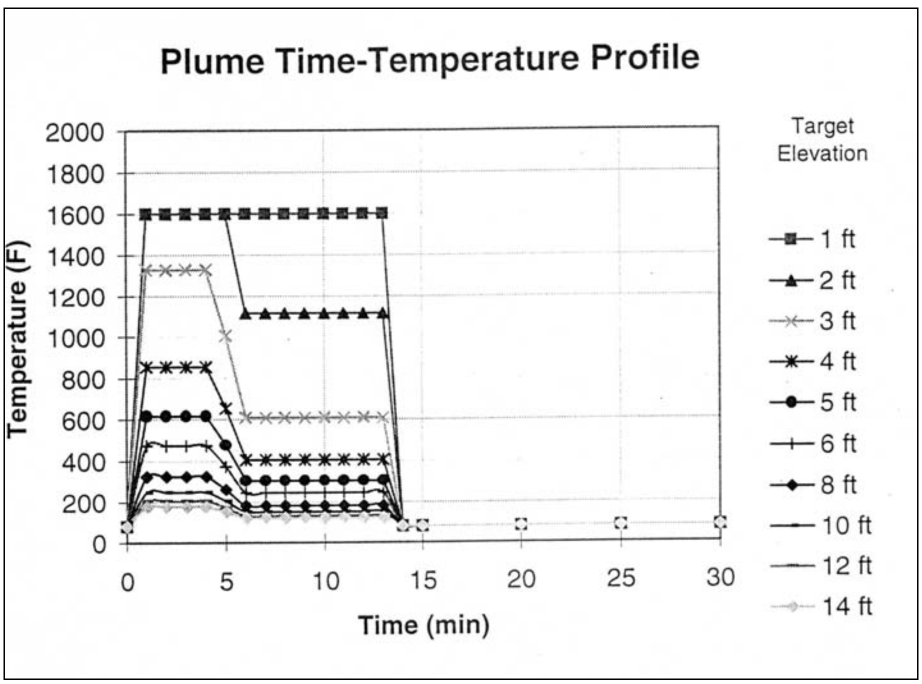

Figure 6. Column Exposure Temperatures from Maintenance Refuse Fire.

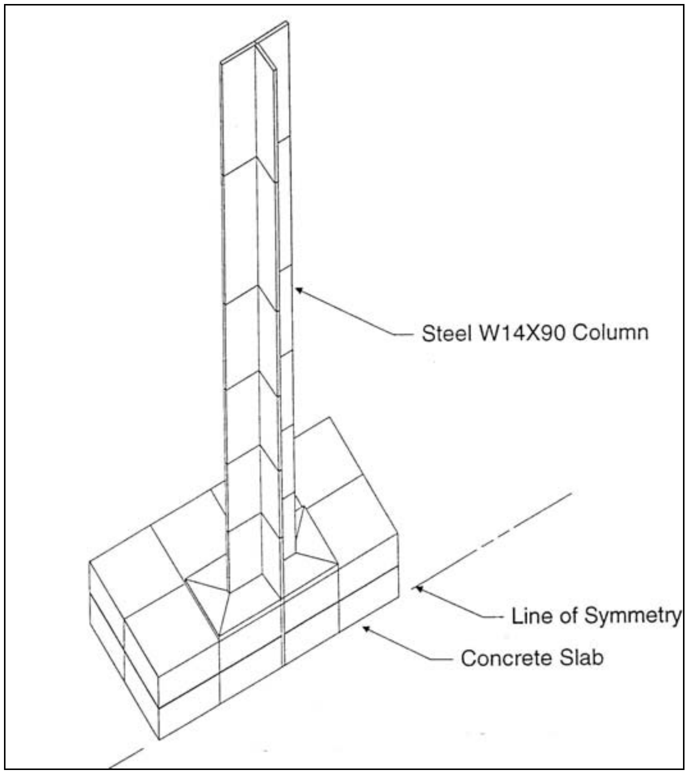

Figure 7. Column, Adjacent Base Plate and Floor Slab Discretized into Finite Element Mesh.

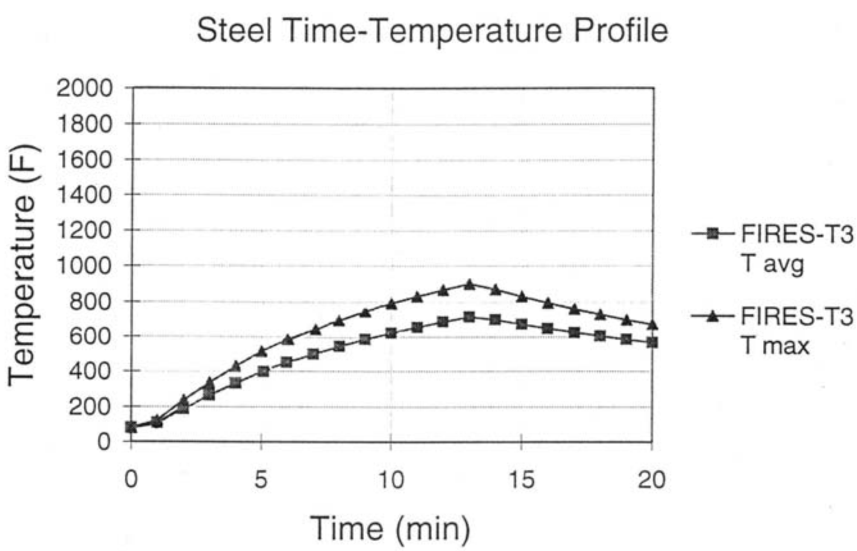

Figure 8. Steel Temperature History for Maintenance Refuse Fire.

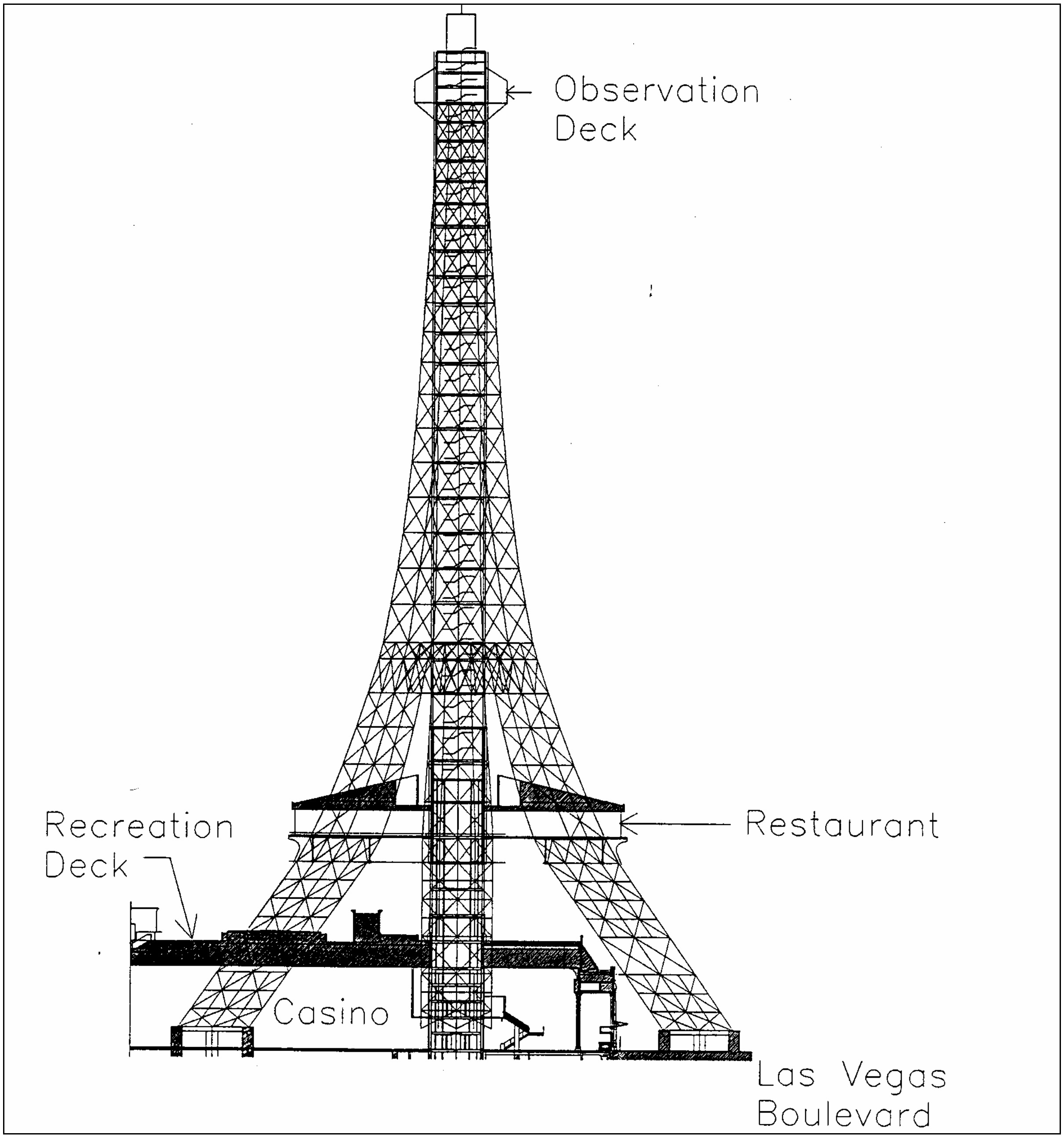

Figure 9. Eiffel Tower II.

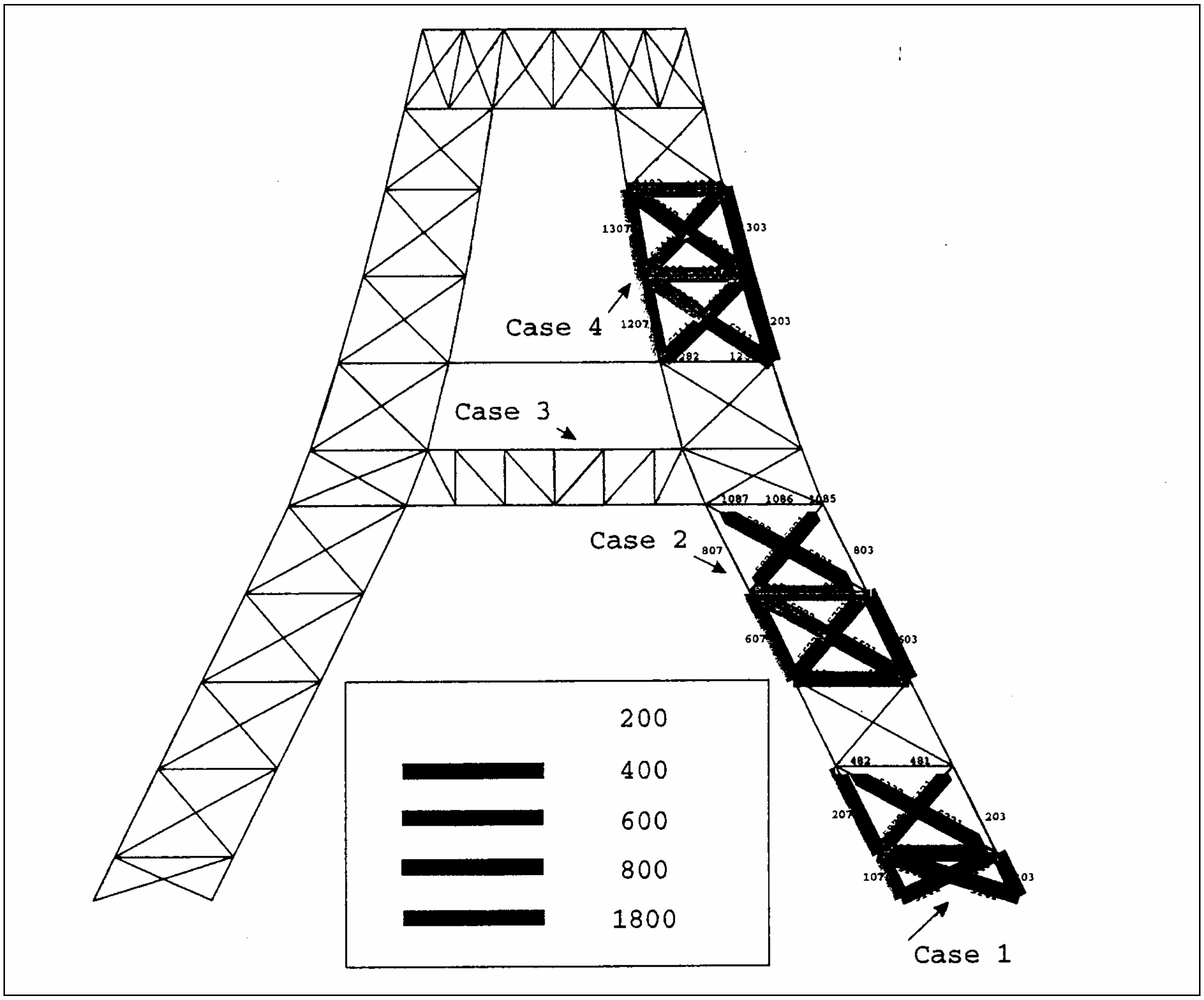

Figure 10. Calculated Steel Temperatures in Eiffel Tower II for Four Fire Scenarios.

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Structural Fire Protection

The current practice in structural fire protection in the US is based on test methods developed a hundred years ago and test requirements developed on the basis of the fire science of the 1920's. While changes in the test methods and the requirements have evolved over the years, the bases and principles have not changed. Thus, the opportunities for significant innovation in reliable and cost effective structural fire protection are great.

NAS workshop papers and presentations in the area of structural fire protection were provided by Milke, Iding, and Kodur. The committee thanks these individuals for their contribution to the work of the committee.

Historical Perspective

At the turn of the century there was intense interest in structural fire protection as a result of many severe urban fires that destroyed whole areas of the respective cities. Furnace test methods to assess the structural performance of elements of building assemblies were developed and over time the many different furnace testing protocols were integrated to form the basis of the furnace test methods used throughout the 20th century. Out of this process arose the standard time-temperature exposure curve that is still used today (AISI 1979). In the 1920's Ingberg, at the National Bureau of Standards, developed test duration requirements in the then standard time-temperature exposure based on expected fuel loads for various occupancies (Ingberg 1928). These developments predated modern fire science and do not reflect our modern understanding of the role of ventilation on the severity of fires environments.

In the 1950's Kawagoe and others recognized the role of ventilation in fire severity. The buoyant flow of air to support combustion was mathematically modeled by Kawagoe (1958) and the primary role of the opening factor, $A\sqrt{H}$, was recognized. A is the area of the opening and H is the height of the opening. In the decade or two following this work, a full mathematical description of fully developed fires emerged based on conservation of energy for the compartment, using the air flow model of Kawagoe, heat conduction through the bounding materials, and simple radiative/convective heat transfer modeling (Kawageo and Sekine 1963, Odeen 1963, Magnusson and Thelandersson 1970, Babraukas and Williamson 1978) By the early 1970's, hundreds of tests had been conducted throughout the world and several fire models were being used to predict the outcomes of these tests. The most ambitious experimental program was organized by Phillip Thomas under the auspices of the CIB (Thomas and Heselden 1972). During this time, it was widely recognized that the existing standard time-temperature curve did not represent real fully developed fire conditions. In most cases the standard exposure was less severe than real fires, though the standard exposure was generally longer than real fires.

At the same time, heat transfer and structural analysis methods based on finite difference and finite element methods were emerging, fueled by the ever-growing computational capabilities of computers. By the end of the 1960's, computational methods for predicting the heating and deformation of steel and reinforced concrete building elements were available and in use in research and advanced engineering practice.

Sweden recognized the value of scientifically based structural fire protection design, and undertook the development of a national structural fire protection design method based on the modern science in the 1970's. By 1976 Sweden had a modern structural fire protection infrastructure in place (Pettersson et.al. 1976). Similar methods had evolved worldwide during this period and at least one textbook (Lie 1972) reflected the modern methods.

In the US and elsewhere the old prescriptive methods continued to be used in building code requirements. While the modern analytical methods had been developed, the building code community did not embrace the technology. As a result, the methods never came into general use. Even today, analytical methods in structural fire protection are only used in special circumstances.

The reliance on antiquated methods results in uncertain performance and inefficient design. Many buildings are likely significantly overprotected while others may not be capable of resisting fire threats to the extent generally expected. This represents an opportunity to significantly improve structural fire protection design methods. At the same time, the lack of attention to technology transfer in earlier decades points to potential pitfalls that need to be addressed.

Outstanding Technical Issues

While a significant technical basis for structural fire protection design is available, research in this area has been ignored in the US for decades. As a result, there is work that needs to be done to recreate a technical basis for 21st century design. While the work in the 1960's and 1970's was of high quality in its day, the work does not satisfy current standards of experimental and theoretical research. While structural fire protection has been ignored as a research area, available applicable computational and experimental methods have changed monumentally in the past decades. There is a need to bring the methods of the 1970's up to date with modern methods. In addition, the changes in materials and construction methods over the decades has left holes our basic knowledge base. Finally, research over the past decades has shown that the 1970's scientific knowledge of structural fire protection was incomplete in ways that are significant in engineering practice. These issues are discussed below in the context of the three basic areas involved in structural fire protection: fully developed fire exposure, heat transfer to and through the structural elements, and the structural response of the element and the structural system to the effects of the fire.

Fire Exposure to the Structure

The existing methods for predicting fire exposure assume that a compartment fire can be characterized as a well-stirred reactor with a single compartment temperature. While this is a reasonable characterization for small compartments with small aspect ratios, there are questions about its applicability to many significant situations in practice. Work in recent years by Thomas and Bennetts (1999) has demonstrated that for large aspect ratio compartments, fires first burn vigorously near the vent and the burning region propagates into the compartment as fuel is consumed near the vent. This gives rise to variations in the time-temperature exposure throughout the compartment. These observations indicate that there may be a need to assess fire resistance on the basis of both a global exposure as well as a local exposure. The global exposure is much like the traditional approach, with a local exposure dictated by the proximity to vent openings and the local fuel load. This bears further attention.

In large spaces, like open plan offices, the evidence from real fires like the First Interstate Bank (Nelson 1989) is that fire growth times are a significant fraction of the overall burning duration for an individual floor. Classical methods treat the fire growth time as insignificant. As such, under these circumstances fire exposures predicted tend to be shorter, but more intense than an actual fire. There is very limited understanding of fire spread in large spaces like open plan offices. There are other large spaces such as industrial facilities in which the idea of a fully developed fire throughout a space is simply not realizable. The notion of flashover is simply not an observed phenomenon and the classical methods that assume the entire space to be involved in fire will most often overestimate the actual fire severity. The trend over the decades to larger and larger industrial and commercial spaces makes investigation of large compartment fire phenomena a very relevant issue.

Beyond these new issues, there are lingering problems in the classical methods even within their range of applicability. All the available models use some form of combustion efficiency parameter to reduce the energy output to achieve agreement with experiments. The model by Babrauskas(1979) uses a combustion efficiency directly, but all the other methods have the effect represented in one manner or another. Typically, the combustion efficiency is in the range of 0.5 to 0.9 (Babrauskas, 1981), with 0.7 the most commonly used value. This range of combustion efficiencies can lead to a very wide range of temperatures and even the nominal value of 0.7 represents an empirical factor reducing the energy output by 30% from the theoretical value. The limited available evidence points to several factors that contribute to this value, so that careful experimentation and analysis will be required to develop an understanding of this significant factor.

Heat Transfer

While modern computational methods in heat transfer are generally capable of fulfill the requirements for heat transfer analysis for structural fire protection, there remain issues to be addressed in this area. Most pressing among these are the development of methods for measuring thermal and mechanical properties of materials over the temperature range of significance in fire. Thermal properties of insulating and structural materials are sometimes available, but the temperature range is generally limited and the methods used have not been fully developed and validated. Much of the data is quite old and modern materials replaced better characterized old materials. A notable example of the effect of innovation in materials can give rise to serious structural fire protection effects is the use of high strength concrete that is very prone to severe spalling (See Kodur). The continuing changes in materials and methods requires ongoing attention to fire issues. Some insulating materials like intumescents require additional study to fully characterize their performance. If well validated test methods were available for property measurements, this would facilitate wider characterization of material properties that are needed to support structural fire protection design.

Mechanical properties of insulating materials have been identified as a largely ignored area of concern. Insulating materials need to be sufficiently robust to remain in place through the abuse of construction and the life of the building, so that the insulation will be in place when they are needed to protect the structure from fire. Beyond this, the materials must possess sufficient mechanical strength to remain in place through the course of the fire exposure. The events of 9/11 have highlighted these issues. There has been little study of the mechanical properties of insulating materials needed to resist ordinary insults. The effect of blast and aircraft impact on the mechanical stability of insulating materials has certainly not been studied adequately. During a fire, it is also known that the standard furnace exposure is less severe in terms of mechanical forces and thermal shock than are many realistic fires. This leaves open the possibility that insulating materials may perform well in the standard test, but fail to remain in place during a more severe, but realistic fire exposure. These issues need to be addressed.

Structural Response to Fire

It has long been recognized that non-linear structural analysis is needed to understand the effect of fire on structural elements. Today there is a rich array of commercial codes generally capable of the required analyses for fire applications. These have, to a limited extent, been applied to fire problems and some comparisons with full scale fire exposure data are available in the scientific literature. While these tools are not in wide application in structural engineering design, the challenges in this area are to validate the available methods and to develop high temperature properties for modern materials.

However, there are additional issues that require serious attention. Current testing methods do not consider structural connections. The design, analysis and protection of structural connections is an area in which there is only a modest technical basis. Here again, the events of 9/11 have highlighted these issues. In WTC 5, there was significant evidence of failures at connections during fire exposure. Any 21st century analysis and design methodology will need to treat these issues, and significant research will be required to support this area.

Current fire testing of structural fire protection methods involves the testing of individual structural elements or subassemblies. Failure criteria employed in the tests bear no direct relationship to the structural environment in which that element or subassembly will be used. There are attempts to deal with issues of restraint, but even here there is only a phenomenological link to the actual structural system design. Clearly, routine testing of full structural assemblies is not feasible or necessary. However, it is important to develop and validate methods to integrate the effects of fire on the structural system as a whole, so that failure modes due to fire that cause unacceptable structural collapse can be avoided. While it is unlikely that full non-linear analysis of the structural system is needed, there is a need to develop and validate means of including local non-linear effects into a full system analysis.

Fire Test Methods

As discussed previously, current structural fire protection design depends entirely on test methods, like ASTM E-119, and prescriptive requirements in the building code. In the context of the issues raised above, there is a need to revisit the E-119 test method itself and its role in structural fire protection generally. It is well known that E-119 does not provide a fire environment as severe as is possible in real fire situations. The time-temperature exposure is much less severe in the early portions of the test and the time rate of change of temperature is modest relative to many fires. A more severe test, like UL 1709, is used in some applications to test the performance of structural fire protection systems. In particular, several years ago the US Navy changed from the E-119 to the UL 1709 exposure for qualification of structural fire protection systems for shipboard use. This change eliminated some systems from use due to their inability to remain in place during the more severe fire exposure.

Beyond the particulars of the test methods, the entire role of furnace fire testing in structural fire protection bears review and assessment. A modern approach to structural fire protection would involve the use of small scale tests to measure thermal and mechanical properties for use in models. The models would form the basis for analysis and design. The role of furnace fire testing would, in this approach, serve the role of validation of the combined performance of small scale material characterization tests and the fire/thermal/structural modeling of the fire exposure and response. Such validation might require significant changes in the way tests are performed. Currently, assemblies are not tested to failure. If they pass the failure criteria through the desired duration, the test is stopped without failure. This, of course, would not test the ability of the analytical method to predict the failure mode. Testing to failure may be required in a modern furnace test method.

Potential for Breakthroughs in Structural Fire Protection

While the prior section has identified several areas of required research, it also clearly illustrates that science-based structural fire protection design is definitely technically achievable. As noted previously, the challenges of technology transfer need to be taken seriously.

The environment to make the change to science-based structural fire protection design has never been more favorable. The events of 9/11 have highlighted the issues both in the engineering community and our society at large. There has been wide coverage in newpapers, magazines, and television shows of the role of structural fire protection issues in the 9/11 tragedy. In particular, several months ago an article on the role of the E-119 furnace test in structural fire protection appeared in the N.Y. Times (Glaser et.al. 2002). Prior to 9/11, such an article was unthinkable.

Beyond the broad coverage of the issue in the popular press, the events of 9/11 have motivated organizations like the Amercian Society for Testing and Materials (ASTM), Underwriters Laboratory (UL), American Society of Civil Engineers (ASCE), Society of Fire Protection Engineers (SFPE), and the National Institute for Standards and Technology (NIST) to reexamine the practice of structural fire protection design in the US. The report of the Federal Emergency Management Administration (FEMA) report on the World Trade Center (WTC) tragedy specifically identified the need for study of structural fire protection (FEMA 2002).

This motivation builds upon preexisting commitments in the engineering community to improve the practice of structural fire protection design. ASCE and SFPE had a joint project underway prior to 9/11 to bring together existing knowledge in this area to improve engineering practice. Prior to 9/11 NIST had planned a workshop on structural fire protection with the intention of focusing research in this area. The report of the workshop, held in February 2002, provides a focus of research, education, and technology needs in structural fire protection (Grosshandler 2002).

All these factors point to a general appreciation for the need for change by organizations and institutions that are needed to transfer scientific knowledge to standards and methodologies needed for advancement of the practice of structural fire protection design. NSF has a key role to play in this process.

NSF is the home of academic scientific research funding in this country. Through its role in this research area, NSF will bring scientific credibility to the process, and will attract academic researchers needed for both research and training of the next generation of structural fire protection designers. Beyond this, NSF has experience in other emerging structural engineering areas like earthquake engineering that will facilitate the process of conducting and implementing breakthrough scientifically-based engineering methods.

Not only does NSF have experience in similar emerging areas, but also is a player in multi-hazard and extreme event hazard analysis. There are clear interconnections with these efforts. In fact, fire is a significant factor in damage due to earthquakes and the research in this area of earthquake engineering has been lacking. Direct focus on structural fire protection would also generate technical interest and synergies in other multi-hazard areas of importance to NSF.

Structural fire protection clearly is a clear challenge and opportunity for NSF and the nation. This is a unique time in history to address this challenge. NSF, downstream engineering organizations, and our nation as a whole are motivated and prepared to undertake a coordinated attack on this problem.

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The Fire Problem

John W. Lyons

Workshop at the National Research Council
April 15-16, 2002

Unwanted fire has always been a problem but the nature of the problem has evolved over the centuries. Since people began living in cities large conflagrations have occurred fairly regularly. A classic example is the Great London Fire of 1666, which combined with the plague made life miserable as well as exceptionally hazardous. Despite the fire Londoners were not benefited by tax-supported fire services until the 1860's. Beginning at about that time in the United States steps began to be taken to reduce the chances of large multi-building fires. By 1900 the first building codes came into play calling for building separations, fire walls, escapes and the like. Water mains had been placed appropriately to give some assurance that fire services had sources of water to pump onto fires. The result: relatively few widespread conflagrations have occurred since. (Those that have include the San Francisco fire (1906) due to earthquake, the Baltimore fire (1904), and two fires at Chelsea, MA.)

Attention then turned to reducing the severity of fires within individual buildings, given ignitions. Test methods and standards began to specify levels of fire resistance for structural members and some interior finishes. By mid-century large, multi-occupancy buildings had columns and beams of a given level of resistance to heating from fires, stairwells are protected by fire doors, standpipes bring water to upper floors, and sprinklers and various detectors stand guard. As a result we rarely lose entire large buildings to fire. (The disaster at the World Trade Center had a cause so severe as to overcome the fire and life safety provisions of the building code.)

And yet in the late 1960's and early 1970's the Congress of the United States became sufficiently concerned about unwanted fire that they enacted several pieces of legislation aimed at reducing the Nation's fire losses. Why?

Some answers are in the Report of the National Commission on Fire Prevention and Control, a Congressionally chartered group to assess the fire problem and recommend remedial actions. The Commission reviewed the loss picture and presented the following figures (ref.1):

12,000 deaths
300,000 injuries
$11.4 costs

In addition, firefighters were being killed at a rate of near 200 a year and suffered injuries at the incredible rate of 39.6 per hundred per year.

The Commission said that the United States led all civilized nations in the world in per capita deaths and injuries: death rates near twice those of Canada the second worst performer and costs one third higher than the Canadians.

The Commission attributed these dreary figures to ignorance, carelessness, and lack of an emphasis on prevention in community governments and the fire services themselves.

The report led to passage of the Federal Fire Prevention and Control Act of 1974. The Act established the Fire Administration, the Fire Academy, and the Fire Research Center at the National Bureau of Standards. This was the first serious attempt at a Federal presence in the fire safety arena.

At the Fire Research Center we set about to analyze the dominant causes of losses due to unwanted fires through analysis of fire scenarios. (ref.2) By studying the available information we concluded that most losses in terms of fatalities and associated injuries occurred in residences. The reasons soon became apparent. Single family residences were not very well controlled by building and fire codes as compared to large multi-occupancy buildings. In the home there were open stairwells, few regulations as to materials used in furnishings, no sprinklers, and in those days few to no detectors. Few people had home fire extinguishers. And there were many different ignition sources also poorly covered by any sort of standards or codes. The initial NBS fire research programs were tailored to provide technology for intervening in the various scenarios. A Fire Research Plan was published (ref.2) to inform the community of the directions we were heading.

Now, over a quarter of a century later, where are we? Are we still the world's worst in terms of per capita losses? Do we have a better handle on the root causes? Let's have a look.

The National Fire Protection Association annually publishes a digest of fire losses in the United States. The most recent figures (ref 3) are for the year 2000:

Deaths	4045 (3445 in residences)
Injuries	22,000
Costs	$11.2 billion

We should note that the figure for deaths in "America Burning" were subsequently revised, in 1977 (ref.4), from 12,000 to 8800, the difference being in the deaths attributed to transportation fires; these were dramatically reduced. The drop since then is over 50%. A lowering of losses by 50% in about 14 years (ref. 1, p8) was the goal enunciated in "America Burning". The goal taken later by the Fire Research Center was 50% fewer deaths by the end of the century. That has been attained.

Note also that the figures for injuries have changed. In America Burning, I believe the injuries were for all burns reported to hospitals or public health officials. When these are restricted to unwanted fire they drop by over half. When fire fighter injuries are removed we find the level of civilian injuries from fire in the range of between 20,000 and 30,000 a year.

The cost figures also have been worked over several times. The total depends on how figures are computed for direct and indirect fire losses. A study funded by the NIST Center for Fire Research in 1991(ref.5) put the total at well over $100 billion. This figure included direct costs, and indirects for insurance, fire services, the extra costs in buildings and materials for complying with fire safety provisions in the codes, and the like. The total is about ten times the direct costs.

The path to lower figures for deaths is shown in Figs. 1 - 3 obtained from John Hall at NFPA. Fires in residences (Fig.1) continue to dominate the fatality data. The international data (Fig.2) show the U.S. and Canada dominating the death rates and declining steadily. The surprise is that Japan's data have risen to match the U.S. in recent years. Fig.3 shows the principal causes of fire and of fire deaths. Whereas cooking causes most fires, smoking causes most deaths. Two fairly recent papers (ref 6. and 7.) present details. Table 1 taken from ref. 6 breaks down losses by equipment involved in fires in the home, reflecting CPSC's interests in products. Table 2 shows the primary cause of fatalities is consistently smoke inhalation. The final NFPA chart from John Hall (Fig.4) I found startling: most fire service responses are now for HazMat incidents and Emergency Medical emergencies. Only 8.3% of calls are for fires.

Various workers have sought detailed explanations for fire losses in different occupancies, in different parts of the country, and in different ethnic populations. NFPA every year discusses some aspect of the fire loss figures. Phil Schaenman, first director of the fire data group at the U.S. Fire Administration, has spent a lot of effort and time over the past twenty five years developing an understanding of the underlying factors.   Every study of the differences between the United States data and those of countries in Europe and Asia conclude that the attitude of the state and the public is key. In Japan it has long been a serious social offense

to have a fire on one's property; until fairly recently it was a crime. Investments in fire prevention and in the fire services are sufficient to provide superior equipment, education, and training. Schaenman notes that the fire losses for Hispanics in various countries are low - about half that of the U.S. But when they emigrate to the U.S. the rates rise. But is this because of attitudes, or different housing, more flammable furnishings and the like. There is a lot to be learned at this level of detail.

How does one decide if the current loss figures are too high and if so by how much? Back in 1974 we took the first goal of reducing fire deaths by half, but we knew that if we could do that it would not be the end - that we would then have to set a new goal. Since we are still doing poorly compared to most other countries there remains room for more reduction. How much? Will it be good enough to match, say, Great Britain? Japan?

I suspect we would want to keep going. Even one death from a fire that didn't need to happen would be unacceptable. Thousands are certainly so.

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NORTHWESTERN UNIVERSITY

RE: ITAR Amendment—Category CII July 2, 2015

TO: DDTCPublicComments@state.gov

I am a professor of Electrical Engineering at Northwestern University where I am conducting fundamental research related to the development of Type-II superlattices (GaSb/InAs and InGaAs/InAs) based focal plane arrays (FPAs) as a next generation replacement for existing MCT FPAs. I have demonstrated some of the world's first 320×256, 640×512, and 1024×1024 FPAs covering the SWIR, MWIR, and the LWIR spectral regions as well as 320×256 and 640×512 dual-band multispectral combination of the those wavelengths. Over the years, my work on Type-II superlattices has been funded by DoD agencies like DARPA, MDA, NRO, Army Night Vision Labs, as well as by civilian agencies like NASA. I feel that I have done a great service to this country in driving the development of this technology.

As a university Principal Investigator I work with a multi-national group of students, post-doctoral scholars, and research faculty; this multi-nationalism is a fundamental aspect of university research, as is the expectation of being able to openly publish the results of that fundamental research. For the last several years, I have struggled with stifling attempts to impose ***DFARs 252.2-4-7001***- *Disclosure of Information* restrictions on fundamental research related to Type-II superlattice based IR-FPA. The proposed changes to the munitions list are overly broad and will place almost all IR-FPA research (fundamental, existing, or otherwise) under the purvey of ITAR restrictions. This would almost certainly prevent me from continuing my important research, and would have a major stifling effect on the overall research and development of Type-II superlattices. As such, I would like to offer my comments on the proposed changes to the International Traffic in Arms Regulations (ITAR) to revise Category XII:.

COMMENT #1 (RE RFC #4): Infrared focal plane arrays (IRFPAs) are in normal use, and information about their development is already widely in the public domain. It would be a major step backwards for fundamental science to try and retroactively apply ITAR classification to this technology. We published our first Type-II superlattice LWIR IRFPA results in 2006.[1] By 2010 we had already demonstrated the world's first 1024 x 1024 LWIR IRFPA based on that technology.[2] In 2011 we demonstrated the World's first 320x256 two color (multi-spectral) LWRI-LWIR IRFPAs[3] and the World's first 640x512 two color LWRI-LWIR IRFPAs[4]. Sections C(2), C(4), and C(12)(ix) suggest that any SWIR, MWIR, or LWIR IRFPA with more than 256 elements, or Sections C(6) and C(12)(x) suggest that any multi-spectral IRFPA at all, would be classified as a munitions item if it were integrated into a "permanent encapsulated sensor assembly". Unfortunately, this phasing is overly broad in scope as the concept of a permanent encapsulated sensor is not well defined. The simple act of hybridizing an IRFPA to a ROIC, under-filling it, removing the substrates, and bonding it to a leadless-

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[1] M. Razeghi, P.Y. Delaunay, B.M. Nguyen, A. Hood, D. Hoffman, R. McClintock, Y. Wei, E. Michel, V. Nathan and M. Tidrow, *IEEE LEOS Newsletter,* **20**(5), (2006)

[2] P. Manurkar, S.R. Darvish, B.M. Nguyen, M. Razeghi and J. Hubbs, *App. Phys, Lett.,* **97**(19), (2010).

[3] E.K.Huang, A.Haddadi, G.Chen, B.M. Nguyen, M.A. Hoang, R. McClintock, M. Stegall, and M Razeghi, OSA Opt. Lett. **36**, 2560 (2011).

[4] E.K. Huang, A. Haddadi, G. Chen, A.M. Hoang, and M. Razeghi. *Optics Lett.*, **37**, p. 4744-4746 (2012).

ceramic chip carrier (LCCC) considered to be 'permanent encapsulation' and thus may be considered sufficient to trigger restrictions. Unfortunately, this is the minimum level of integration required to test an IRFPA.

COMMENT #2 (General Comment): References to "256 elements" in C(4) and C(12)(iv) appear to be in error when considering the reference to "640 elements in any one dimension" in Note2 to paragraph (C). It is odd that 640 elements are allows in a linear sensor, but only 256 elements are allowed in a 2D sensor. It would make far more sense that the text was intended to read "256 elements in any one dimension." However, even that text is less than ideal. Commercial small-format ROIC are generally 320×256. It would make far more sense to limit the technology to "sensors having more than 320 elements in any one dimension." That wording would at least allow commercial development of small format single-color IRFPAs to continue; and would only ban multi-color and mid/large format IRFPAs.

COMMENT #3 (RE RFC #5): I already make Integrated Dewar Cooler assemblies using my FPAs. I was funded by the Army under contract W909MY-11-C-0033 to make a 320 x 256 high operating temperature (HOT) MIWR camera system. Under that program we collaborated to develop a single-color 320 x 256 IRFPA core, package it in IDCA, and build electronics around it to create portable camera system. I am currently funded by NASA to make a 1280 x 1024 two-color (LWIR/MWIR) portable camera based on similar technology. This is important research, and these high resolution dual-color cameras are highly needed by NASA for future space missions—so much so that I am just beginning a new project with NASA to look into the fiesabiliyt of delivering a 1280x1024 LWIR/LWIR two color camera to them. Whole-scale application of ITAR to IRFPAs larger than 256 pixels, or to multi-spectra IRFPAs would jeopardize my ability to continue to perform on important fundamental research efforts like this. If a "bright line" is to be set, then it should be set at the 2 Mega-Pixel level as technology like that is currently only done by defense contractors, while two-color and 1 Mega-Pixel FPAs are regularly being fabricated by university research labs like mine.

COMMENT #4 (RE RFC #5): The commercial Cryo-Coolers we are using all have MTBFs of around 10,000 hours (RICOR USA). This is well in excess of 3000 hours specified by Section C(9)(i). It is almost impossible to find a commercial cryo-cooler to use in our camera fabrication with a MTBF of less than 3000 hours. The shortest MTBF cryo-cooler that RICOR USA sells has a MTBF of 8,000 hours. That means that creating a 77K IDCA would require a custom cryo-cooler, and all of the extra cost associated with that endeavor. And, in the end, the cooler they delivered would probably be little more than a re-branded version of an existing cooler where the quoted MTBF was 3,000. Forcing researchers seek out short-lived cooler for their fundamental camera system research would significantly hinder ongoing research with no tangible benefit.

COMMENT #5 (RE RFC #5): I hold the principal patents on Type-II superlattice based IRFPAs.[5,6] These IRFPAs and integrated IRFPA cameras based on Tyep-II superlattices are already commercially available form a number of suppliers. QmagiQ currently commercially sells 320x256 single and dual band IRFPA camera systems, as well as 640x256 single color systems. They have also reported on 1kx1k single color cameras, but do not currently offer them for sale. AIM (Germany), IR-Nova (Sweeden), and Sofradir -IC (France) also sell MWIR IRFPAs and integrated modules based on Type-II

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[5] US patent number 7001794, "Focal Plane Arrays in Type-II Superlattices" (2004) .
[6] US patent number 6864552, "Focal Plane Arrays in Type-II Superlattices" (2004)

Superlattices. I also have my own small business, MP Technologies, LLC that is dedicated to commercializing Type-II Superlattice technology. Old style MCT IRFPA technology in single and multi-colors is also available commercially from a wide array of suppliers including: Teledyne Scientific and Imaging (USA), Raytheon (USA), DRS Technologies (USA), Semiconductor Devices (Israel), AIM (Germany), Sofradir -IC (France). The United States' strategic advantage does not lie in having a monopoly on IRFPA technology—we don't. This technology is already available world-wide. Bringing it under the wing of ITAR does nothing to strengthen our strategic advantage—all it does is ensure that the next innovations will not come from our universities, but from somewhere else in the world.

In summary, I will point out that basic research is the lifeblood of innovation. The Department of Defense and other government agencies have recognized this need and are currently investing heavily into university development of IRFPA technologies. However, as the proposed ITAR amendment is worded, the restrictions it will impose heavily overlap previous and ongoing basic fundamental research into IRFPAs and camera systems built on that technology. US regulations must adapt to technological evolution and continue to foster innovation in order to avoid falling behind other countries, both from a scientific and economic standpoint.

Thank you for your consideration.

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To Whom It May Concern:

I am writing this letter to express serious concern with the ITAR amendment, Category XII, which imposes limitations on the dissemination of information related to specific technologies that the Government deems important to National Security. In this case, I believe that the proposed amendment places overly conservative limitations on long wavelength (>1510 nm) laser performance, which is both out-of-date with what exists in the public domain or with what is covered in existing research contracts. The net effect will, in general, stifle fundamental research into long wavelength lasers, which is the lifeblood of innovation for the US.

Though it is recognized that long wavelength lasers can be used for military applications, they are also extremely useful for commercial use. One primary example is research into high power, tunable lasers for chemical detection. This type of application targets detection of toxic industrial chemicals, pollution, atmospheric chemicals, or diseases (based on breath-borne biomarkers). Two sensing modalities currently being investigated are photoacoustic detection and standoff spectroscopy, both of which require high power, possibly tunable, lasers to be effective. Many of the parameters described in the amendment will significantly affect development of laser for these types of systems and basic research into new sensing modalities.

The main problem is the development of new intersubband semiconductor laser technology that intrinsically has a higher input power density (factor of 10) than traditional semiconductor lasers. As a result, the output power density also tends to be much higher, which is a characteristic highly sought after for the applications listed above. The quantum cascade laser emits in the longwave region exclusively and has already publically (in journals and conference presentations) surpassed the power limits imposed by the amendment. Specific examples that should be revised include:

1) Paragraph b(10). Tunable lasers with an output power greater than 1 W. This technology has already been widely developed (>2.4 W) and is key to existing detection systems.[1,2] Higher power lasers are being investigated at universities to improve detection sensitivity. Besides DHS funding, this work is also being funded by NSF, ARPA-E, and NASA. The power level should be increased by an order of magnitude (>10 W in CW ,single mode Fairfield, Single mode emitting spectra) to provide some compatibility with the state-of-the-art and prevent interference with ongoing research and publications by university researchers.
2) Paragraph b(11). Non-tunable, single transverse mode, laser with an average or CW output power greater than 2 W. This power limits is severely out of date. Basic research funded by DARPA to improving the intrinsic power conversion efficiency of long wavelength lasers led to over 5 W of CW output power at room temperature and over 10 W of CW output power at cryogenic temperatures.[3] This was published 4 years ago. Improving power conversion efficiency in long wavelength lasers is a multidisciplinary effort being pursued by many groups throughout the US. The power limit needs to be increased significantly (>20 W in CW, with Single mode far field and single mode emitting spectra) in order to not interfere with existing fundamental research. In addition, for all laser categories, some operating temperature must be specified (for example T> 30 °C). Low temperature devices output significantly higher powers, but are not easily utilized for military applications due to the need for large quantities of cryogen.

3) Paragraph b(12). Non-tunable, multiple transverse mode, laser with an average or CW output power greater than 2 W. Power scaling in long wavelength lasers is being investigated both for standoff spectroscopy and free space communication applications. One way of achieving this is to widen the optical cavity, which produces multiple transverse modes. Interplay between laser modal stability, laser cavity geometry, and thermal gradients is a fundamental study which is supported by the National Science Foundation. This has recently led to the discovery of a new type of laser cavity geometry with extremely high power output potential.[4] Though peak power scaling was part of the initial discovery, studying device modal characteristics at higher average powers is a critical part of this work. Restricting publication in this area with stifle this area of fundamental research. Also, in general, multiple transverse mode lasers are easier to produce than single transverse mode lasers and often have even higher output power. Given a similar argument to #2 above, at the very least, an even higher power level limit must be applied to these lasers (>100W in CW, single mode far field and single mode emitting spectra.).
4) Paragraph b(13) regarding stacks of laser arrays. Due the high input (and therefore output) power density of the quantum cascade laser, the longwave stacked laser array power density limits and CW power limits should also be increased by roughly a factor of 10. A non-ITAR SBIR program is currently underway by the Navy to develop >100 W CW arrays of these lasers. Once work from this program is publicized, the current amendment power levels will be obsolete.

In summary, I will point out that basic research is the lifeblood of innovation. The Department of Defense and other government agencies has recognized this need and invests heavily into university development of new longwave laser technologies. As the current ITAR amendment is worded, the restrictions it imposes heavily overlap previous or ongoing basic research into longwave laser technology which benefits both military and civilian applications. US regulations must adapt to technological evolution in order to avoid falling behind other countries, both from a scientific and economical standpoint.

Thank you for your consideration.

Manijeh Razeghi

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[1] Q. Y. Lu, Y. Bai, N. Bandyopadhyay, S. Slivken and M. Razeghi, "2.4 W room temperature continuous wave operation of distributed feedback quantum cascade lasers," Appl. Phys. Lett. **98**, 181106 (2011)

[2] Y. Ma, R. Lewicki, M. Razeghi, F.K. Tittel, "QEPAS based ppb-level detection of CO and N2O using a high power CW DFB-QCL." Optics Express **21**, 1008 (2013)

[3] Y. Bai, N. Bandyopadhyay, S. Tsao, S. Slivken and M. Razeghi, "Room temperature quantum cascade lasers with 27% wall plug efficiency," Appl. Phys. Lett., 98, p. 181102 (2011).

From:	john@jmpa.us on behalf of John Palatiello
To:	DDTCPublicComments
Subject:	"ITAR Amendment—Category XII."
Date:	Monday, July 06, 2015 1:23:46 PM

Directorate of Defense Trade Controls

DDTCPublicComments@state.gov

Washington, DC

Subject: "ITAR Amendment—Category XII."

MAPPS is pleased to provide these comments in response to the May 5, 2015 *Federal Register* notice whereby the Department of State, Directorate of Defense Controls (DDTC) solicited comments on the implementation of Export Control Reform (ECR) with respect to fire control, range finder, optical and guidance and control equipment.

MAPPS, the trade association of private sector geospatial firms is deeply concerned that unnecessary export control restrictions could hinder growth in the geospatial business sector.

Geospatial is essentially the surveying, mapping and geographic information business. The Department of Labor included geospatial as one of just fourteen High Growth sectors of the U.S. economy workforce, projected to add substantial numbers of new jobs to the economy or affect the growth of other industries or where there are existing or emerging businesses being transformed by technology and innovation requiring new skills sets for workers to prepare workers to take advantage of new and increasing job opportunities in high-growth, high-demand, and economically vital sectors of the American economy.

It is widely accepted that 80 to 90 percent of government information has a geospatial component.

Of the available records on www.data.gov, over 90 percent of the data is geospatial. Geospatial is a rapidly changing technology and engineering field.

A recent market study reported that the geospatial field is a $73 billion market that drives more than $1 trillion in economic activity and more than 500,000 American jobs are related to the collection, storage and dissemination of geospatial data, and another 5.3 million workers utilize such data.

From natural resource management to infrastructure projects, and a variety of other applications such as E911 systems, precision agriculture, environmental protection, recreation, flood plain mapping, equitable assessment of local property taxes, emergency preparedness and response, the Census, geospatial data is being put to use in our everyday lives. Millions of Americans now routinely use geospatial and GPS data in navigation systems, on-board vehicles and handheld devices.

MAPPS is concerned the proposed rules place new controls on certain existing commercial geospatial systems and equipment products that fails to establish a “bright line” between the military (USML) and commercial (CCL) designations, particularly for imaging, GPS and LiDAR systems. The proposed changes to USML Category XII could disadvantage our U.S. manufacturers and operators when competing for commercial applications against foreign competitors.

Such proposed revisions to Category XII(b) would result in the transfer of many commercial products to the USML that were previously not USML controlled. These products were designed, and are predominately used, for commercial applications. They were not designed for military use.

The fact that such existing commercial geospatial systems may possess parameters or characteristics that provide a military advantage means that the proposed control of these commercial products would blur the “bright line”, rather than clarify. MAPPS believes the government and private sector would benefit from clearly specifying that such items are controlled in the USML only if they are particularly designed for military use.

It is our understanding that the intent of the regulations is that items that are in normal commercial use and not specially designed for military use would not become subject to the USML. At the same time, we recognize that such items may possess characteristics that could be used for military or intelligence applications. We do not believe that the USML should control such items unless they have been specially designed for military use.

Domestically, the U.S. government has embarked on a national LiDAR program, known as 3DEP, managed by the U.S. Geological Survey. This civilian agency program, carried out by commercial professional service firms by contract to USGS, is an example of the societal benefits of LiDAR. Please visit www.3DEP4America.com for information on this program and its civilian benefits. Additionally, aerial imagery and GPS use for geodetic control survey are part of the National Spatial Data Infrastructure (NSDI), which has been a domestic, Federal, civil agency program since 1994. MAPPS cautions against limits on the use of technologies for CCL in foreign markets, or as USML, when they are ubiquitous in the domestic civil/commercial market. We believe such a designation would have serious, unintended and negative consequences for U.S. foreign policy and the economic well being of American companies in the export market.

Individual MAPPS member firms, including system manufacturers and service firms that utilize such systems, particularly when working on overseas projects, will be submitting specific comments with regard to their systems. MAPPS respectfully urges the government's careful consideration of these comments and cautions that jobs could be lost and business in exporting will be jeopardized if care is not taken with regard to the treatment of these geospatial systems. This will not benefit U.S. national security, as such systems or will be obtained or deployed from our foreign competitors.

We appreciate your consideration of our views.

Sincerely,

John M. Palatiello
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BEFORE THE

Department of State

Washington, DC

In the Matter of Proposed Rule Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII	RIN 1400-AD32 Public Notice 9110

To: Directorate, Defense Trade Controls, Department of State (DDTC)

COMMENTS OF MATTHEW J. LANCASTER

Introduction

1. These observations relate to the proposed control of technical data, defense services, software, and technology under proposed revisions to United States Munitions List (USML) Category XII – Fire Control, Range Finder, Optical and Guidance and Control Equipment (hereinafter "USML Cat. XII").

2. This set of comments first probes the potential forward and reverse implications of USML Cat. XII(f); then recommends some alternative language to obtain the assumed goal.

BACKGROUND

The Asterisk

3. USML Cat. XII(f), upon initial inspection, appears to resemble most of its counterparts in other USML categories having already undergone complete transformation to publication as part of the President's Export Control Reform initiative (ECR):

> ***(f) Technical data (as defined in § 120.10 of this subchapter) and defense services (as defined in § 120.9 of this subchapter) directly related to the defense articles enumerated in paragraphs (a) through (e) of this category. (See § 125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)**

4. In fact, I read this paragraph more than a half dozen times before realizing it myself for the first time that USML Cat. XII(f) opens with an asterisk (*).

5. ITAR § 121.1(b)(3) notes:

> ***Significant military equipment.*** **An asterisk may precede an entry in a U.S. Munitions List category. The asterisk means the enumerated defense article is deemed to be "Significant Military Equipment" to the extent specified in §120.7 of this subchapter. Note that technical data directly related to the manufacture or production of any defense articles enumerated in any category designated as Significant Military Equipment (SME) is also designated as SME.**
> [italics in original].

6. Does DDTC intend for all technical data (to include software) and defense services classifying under USML Cat. XII(f) to be treated as SME?

7. If so, USML Cat. XII(f) will be almost singularly unique among its counterparts.

8. USML Cat. XII(f), if SME, would also be unique in that neither USML Cat. XII(d) nor USML Cat. XII(e) contain any SME, which would mean that technical data (to include software) and defense services for such non-SME hardware would itself be SME.

9. As a side note, it is also interesting that USML Cat. XII(e)(15), which appears to capture certain classified hardware, is not designated SME.

10. I could find no other similar entry on the USML which is not designated SME.

11. My interest was dually piqued upon reading Note to paragraph (e), which would appear to make such USML Cat. XII classified hardware "subject to the EAR when, prior

to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable."

12. But back to my initial point, I believe that USML Cat. XII(f) has been designated SME in error, but wish to draw DDTC attention to the supposed mistake in order to rectify it prior to publication.

Are the Reverse Implications for the Phrase "directly related to" Intended and Correct?

13. Note 1 to paragraph (f) under USML Cat. XII(f) states:

> **Technical data and defense services directly related to image intensifier tubes [(IITs)] and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.**
> [emphasis added].

14. In sum, Note 1 to paragraph (f) says that "technical data [(to include software)] and defense services directly related to [certain defense articles] remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR."

15. The reverse implication of Note 1 to paragraph (f) is that technical data (to include software) and defense services directly related to all other USML Cat. XII defense articles do not remain subject to the ITAR if (especially if?!) the technical data (to include software) or defense services could also apply to items subject to the EAR.

16. Furthermore, the reverse implication of Note 1 to paragraph (f) is that technical data (to include software) and defense services directly related to all other USML defense articles – across the board – do not remain subject to the ITAR if the technical

data (to include software) or defense services could also apply to items subject to the EAR.

17. In sum, a possible reading of Note 1 to paragraph (f) is that a hidden definition for the phrase “directly related to” exists in the reverse implication of Note 1 to paragraph (f), which is that with respect to technical data (to include software) and defense services, if it could also apply to items subject to the EAR, it does not remain subject to the ITAR.

18. While the reverse implication of Note 1 to paragraph (f), with its hidden definition for the phrase “directly related to”, would bring much-needed clarity and simplicity to the ITAR, it would also transform the phrase “directly related to” into a more liberal release mechanism than that embodied by the definition of the phrase “specially designed” at ITAR § 120.41, and I find it difficult to believe, without more, that DDTC intended this result to issue by virtue of USML Cat. XII.

19. Did DDTC write Note 1 to paragraph (f) with the intention that a reverse implication should be drawn from Note 1 to paragraph (f) and applied to the rest of the USML with respect to the intersection of the phrase “directly related to” with technical data (to include software) and defense services?

20. If not, did DDTC write Note 1 to paragraph (f) with the intention that a reverse implication should be drawn from Note 1 to paragraph (f) and applied to the rest of USML Cat. XII with respect to the intersection of the phrase “directly related to” with technical data (to include software) and defense services?

21. If not, why did DDTC write Note 1 to paragraph (f)?

22. Some, including me, have repeatedly urged DDTC to distinguish the application of the term “directly related to” from the definition of “specially designed”; USML Cat. XII demands it.

23. Rather than navigate the issue via promulgation of a labyrinth of notes (each subject to interpretation), I recommend that DDTC deals with the issue more directly.

24. With the exception of revised USML Category IX, DDTC appears to be hesitant to dismantle the old structure for the catch-all listing for technical data and defense services in each USML category.

25. I recommend DDTC shuffle off this stifling coil so that clarity can be brought to the type of control I believe DDTC envisioned in writing Note 1 to paragraph (f).

26. My recommendation is to integrate Note 1 to paragraph (f) into USML Cat. XII(f) as follows:

> (f)**(1)** Technical data (as defined in § 120.10 of this subchapter) **specially designed for** and defense services (as defined in § 120.9 of this subchapter) directly related to the defense articles enumerated in paragraphs (a) through (e) of this category. (See § 125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)
>
> **(2) Technical data (as defined in § 120.10 of this subchapter) directly related to the defense articles enumerated in paragraphs (c)(1), (c)(2), (c)(9) or (e)(3)-(5) of this category. (See § 125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)**

Are the Reverse Implications for "Software" Intended and Correct?

27. Note 2 to paragraph (f) under USML Cat. XII(f) begins:
Software and technical data include:

28. ITAR § 120.10(a)(4) defines technical data to include software, as defined at ITAR § 120.45(f), directly related to defense articles.

29. By listing software and technical data separately in the opening of Note 2 to paragraph (f), DDTC appears to ignore that the ITAR definition of technical data includes software.

30. By ignoring that the ITAR definition of technical data includes software in the opening of Note 2 to paragraph (f), DDTC appears to be making a unique distinction.

31. The reverse implication of the unique distinction is that, with respect to USML Cat. XII(f), technical data does not include software.

32. As noted in Line 3., above, USML Cat. XII(f) appears to resemble most of its counterparts in other USML categories having already undergone complete transformation to publication as part of ECR.

33. As such, the reverse implication of the unique distinction for software versus technical data made in the opening of Note 2 to paragraph (f) could be extended to all other post-ECR USML categories.

34. Did DDTC write the opening to Note 2 to paragraph (f) with the intention that a reverse implication should be drawn from the opening of Note 2 to paragraph (f) and applied to the post-ECR USML with respect to software being excluded from consideration when the term “technical data” is used on its own?

35. If not, did DDTC write the opening to Note 2 to paragraph (f) with the intention that a reverse implication should be drawn from the opening of Note 2 to paragraph (f) and applied to the rest of USML Cat. XII with respect to software being excluded from consideration when the term “technical data” is used on its own?

36. If not, why did DDTC separately call out software from technical data in the opening to Note 2 to paragraph (f)?

37. For reasons described in greater detail below, my ultimate recommendation is to strike the opening to Note 2 to paragraph (f); however, if the opening to Note 2 to paragraph (f) is retained, my recommendation would be to modify in one of two ways.

38. Either:
Software and **other** technical data include:

39. Or:
~~Software and t~~**T**echnical data include**s**:

Are the Reverse Implications for "Technical Data" Intended and Correct?

40. Paragraph A of Note 2 to paragraph (f) states that technical data includes:
Design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters) for lasers described in paragraphs (b)(6) and (b)(9) through (13) of this category, IITs controlled in paragraph (c)(1) of this category and their parts and components controlled in paragraph (e)(2) of this category (including tube sealing techniques, interface techniques within the vacuum space for photocathodes, microchannel plates, phosphor screens, input glass-window faceplates, input or output fiber optics (e.g., inverter)), IRFPAs and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating structures for an IRFPA and detector elements therefor controlled in paragraph (c)(2) or structures for ROICs controlled in paragraph (e)(4) or (5) of this category, and specially designed ROICs controlled in paragraphs (e)(4) and (5) of this category (including bonding or mating (e.g., hybridization of IRFPA detectors and ROICs), prediction or optimization of IRFPAs or ROICs at cryogenic temperatures, junction formation, passivation).

41. In sum, paragraph A of Note 2 to paragraph (f) states that technical data includes "design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters) for [certain defense articles]."

42. The reverse implication of paragraph A to Note 2 to paragraph (f) is that DDTC does not perceive design or manufacturing process descriptions to fall within the definition of technical data at ITAR § 120.10.

43. ITAR § 120.10(a)(1) defines technical data to include:
Information… which is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles.

44. Did DDTC write paragraph A of Note 2 to paragraph (f) with the perspective that design or manufacturing process descriptions do not fall within the definition of technical data at ITAR § 120.10?

45. If not, why did DDTC write paragraph A of Note 2 to paragraph (f)?

46. I do not believe DDTC wrote paragraph A of Note 2 to paragraph (f) intending to imply that, generally, design or manufacturing process descriptions fall outside the ITAR definition of technical data.

47. Rather, I believe DDTC was trying to, for the most part, fashion a carve-out to a carve-out, which became muddy in the multiple draft iterations of USML Cat. XII which were likely to have been circulated internally prior to the publication of this Proposed Rule.

48. As such, and for additional reasons described in greater detail below, my recommendation is to incorporate this carve-out to a carve-out into the definition of technical data in ITAR § 120.10.

49. Also, Note to paragraph A of Note 2 to paragraph (f) states:

> **Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level [sic] packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled [sic] IRFPA.**

50. In partial summary, Note to paragraph A of Note 2 to paragraph (f) states that, insofar as no information on design methodology, engineering analysis, or manufacturing know-how for a USML-controlled IRFPA (hereinafter collectively referred to as “DEM4IRFPA”) is involved, information directly related to incorporating or integrating IRFPAs into higher-level packaged assemblies not enumerated in USML Cat. XII is not ITAR-controlled.

51. A reverse implication of Note to paragraph A of Note 2 to paragraph (f) is that information directly related to incorporating or integrating IRFPAs into higher-level packaged assemblies enumerated in other USML categories is not ITAR-controlled.

52. Did DDTC write paragraph A of Note 2 to paragraph (f) intending to imply that information directly related to incorporating or integrating IRFPAs into higher-level packaged assemblies enumerated in other USML categories is not ITAR-controlled?

53. I believe DDTC did write paragraph A of Note 2 to paragraph (f) intending to imply that information directly related to incorporating or integrating IRFPAs into higher-level packaged assemblies enumerated in other USML categories is not ITAR-controlled.

54. I also believe DDTC did not go far enough in its exclusion.

55. The exclusion only takes into account incorporation and integration activities, and neglects to address lifecycle support for such products.

56. As such, and for additional reasons described in greater detail below, my recommendation is to incorporate an expanded notion of this carve-out into the definition of technical data in ITAR § 120.10.

57. Also in partial summary, Note to paragraph A of Note 2 to paragraph (f) also states that, insofar as no DEM4IRFPA is involved, external interface control documentation (ICD) associated with non-USML-Cat.-XII, yet USML-enumerated, higher-level packaged assemblies incorporating or integrating IRFPAs is not ITAR-controlled technical data.

58. A reverse implication of Note to paragraph A of Note 2 to paragraph (f) is that external ICD associated with higher-level packaged assemblies incorporating or integrating IRFPAs enumerated in other USML categories is not ITAR-controlled.

59. Did DDTC write paragraph A of Note 2 to paragraph (f) intending to imply that external ICD associated with higher-level packaged assemblies incorporating or integrating IRFPAs enumerated in other USML categories is not ITAR-controlled?

60. I believe DDTC did write paragraph A of Note 2 to paragraph (f) intending to imply that external ICD associated with higher-level packaged assemblies incorporating or integrating IRFPAs enumerated in other USML categories is not ITAR-controlled.

61. I also believe that this type of broad carve-out is not best represented by being buried in a note to a single USML category.

62. As such, and for additional reasons described in greater detail below, my recommendation is to incorporate this carve-out into the definition of technical data in ITAR § 120.10.

63. Also in partial summary, Note to paragraph A of Note 2 to paragraph (f) also states that, insofar as no DEM4IRFPA is involved, external ICD associated with assemblies subject to the EAR is not ITAR-controlled.

64. A reverse implication of Note to paragraph A of Note 2 to paragraph (f) is that external ICD associated with EAR-controlled assemblies contains or constitutes information that a reasonable person might construe to be ITAR-controlled technical data, and that, regardless, such external ICD containing or constituting ITAR-controlled technical data is not ITAR-controlled.

65. Did DDTC write paragraph A of Note 2 to paragraph (f) intending to imply that external ICD associated with EAR-controlled assemblies generally contains or constitutes ITAR-controlled technical data, and, furthermore, that, regardless of whether such external ICD contains or constitutes ITAR-controlled technical data, it is not ITAR-controlled?

66. If so, should such a significant proclamation impacting the ITAR definition of technical data appear in a paragraph to a note in a single USML category?

67. This is where the verbiage begins to become incredibly confusing for me.

68. Why do we need a statement in the USML that external ICD for EAR-controlled assemblies is not ITAR-controlled?

69. I believe we do not.

70. As such, my recommendation is to strike this verbiage.

71. Also in partial summary, Note to paragraph A of Note 2 to paragraph (f) also states that, insofar as no DEM4IRFPA is involved, all information related to basic operating instructions and testing results is not ITAR-controlled technical data.

72. Did DDTC write paragraph A of Note 2 to paragraph (f) intending to imply that all information related to basic operating instructions and testing results is not ITAR-controlled technical data?

73. If so, should such a significant proclamation impacting the ITAR definition of technical data appear in a paragraph to a note in a single USML category?

74. I do not believe DDTC intends to imply that all information related to basic operating instructions and testing results is not ITAR-controlled technical data.

75. Rather, I believe that DDTC intended to exclude from the ITAR definition of technical data basic operating instructions and testing results for IFRPAs in higher-level packaged assemblies not enumerated in USML Cat. XII.

76. I believe this exclusion is achieved by incorporating the entire lifecycle of the product into a slightly broader exclusion, which I prefer to capture in the definition of technical data in ITAR § 120.10.

77. As such, my recommendation is to combine paragraph A to Note 2 to paragraph (f) and Note to paragraph A of Note 2 to paragraph (f) into slightly expanded verbiage in the definition of technical data in ITAR § 120.10, as follows:

> (a) Technical data means, for purposes of this subchapter:
>
> (1) Information, other than software as defined in §120.10(a)(4), which is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles. This includes information in the form of blueprints, drawings, photographs, plans, instructions or documentation.
>
> …
>
> (b) The definition in paragraph (a) of this section does not include:
>
> …

(4) provided such information does not include design methodology, engineering analysis, or manufacturing know-how for an infrared focal plane array (IRFPA) in Category XII of part 121 of this subchapter, information directly related to the entire lifecycle for:

(i) IRFPAs in higher-level packaged assemblies not in Category XII of part 121 of this subchapter; or

(ii) external interface control documentation for higher-level packaged assemblies not in Category XII of part 121 of this subchapter; or

(5) provided such information does not include design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters), information directly related to the entire lifecycle for:…

Are the Reverse Implications for Tune-up/Tone-down (TUTD) Software Intended and Correct?

78. Paragraph B of Note 2 to paragraph (f) states:
Software that converts an article controlled in this category into an item subject to the EAR or an item subject to the EAR into an article controlled in this category [(herein referred to as "tune-up/tone-down software" or "TUTD software")] is directly related to the defense article controlled in this category. When a defense article has been converted into an item subject to the EAR through [TUTD] software, the presence of the [TUTD] software that prevents the item from meeting or exceeding a USML control parameter does not make the item subject to the ITAR.

79. In sum, when TUTD software is involved with a USML Cat. XII defense article, the TUTD software is ITAR-controlled.

80. Also in sum, when TUTD software is used to tone-down a defense article to below ITAR control parameters, the former defense article becomes an EAR-controlled item, despite the continuing presence of TUTD software in the toned-down item.

81. The first sentence of paragraph B to Note 2 to paragraph (f) calls out "this category" three (3) times, but the second sentence of paragraph B to Note 2 to paragraph (f) does not call out or reference USML Cat. XII at all.

82. As such, the reverse implication is that the second sentence of paragraph B to Note 2 to paragraph (f) applies to all of the USML.

83. Does DDTC intend for the second sentence of paragraph B of Note 2 to paragraph (f) to be applied as interpretive guidance for all other defense articles on the USML to which TUTD software has been applied?

84. If not, should DDTC reference USML Cat. XII in the second sentence of paragraph B of Note 2?

85. If so, should such a significant policy announcement (Reverse See-Through Rule) for all TUTD software appear in a paragraph to a note in a single USML category?

86. I very much like the idea of a Reverse See-Through Rule for all TUTD software.

87. It is my recommendation that such a proclamation, if intended, be more prominently displayed.

88. As such, as described further below, I recommend incorporation of this Reverse See-Through Rule into the ITAR definition of software at ITAR § 120.45(f).

89. I would additionally recommend establishing that either an existing exemption applies (e.g., ITAR § 125.4(b)(5)) or creating a new exemption for the maintenance (e.g., updates, bug fixes) of TUTD software in an EAR-controlled item.

90. Also, the reverse implication of the first sentence could be that TUTD software involved with defense articles in any other USML category is not “directly related to the defense article controlled in” any other category (i.e., that all other TUTD software is not ITAR-controlled).

91. Does DDTC intend for the first sentence of paragraph B of Note 2 to paragraph (f) to be construed to mean that TUTD software involved with defense articles in any other USML category is not ITAR-controlled?

92. If so, should such a significant proclamation impacting the ITAR definition of software (or technical data) appear in a paragraph to a note in a single USML category?

93 I do not believe DDTC intends to imply that TUTUD software involved with defense articles in any other USML category is not ITAR-controlled.

94. To the contrary, I believe DDTC is likely more inclined to adopt a default position that all TUTD software is, on its face, ITAR-controlled.

95. I also believe that this inclination is better captured in a more prominent display as part of the ITAR definition of software at ITAR § 120.45(f).

96. As such, I recommend that paragraph B of note 2 to paragraph (f) be incorporated into the ITAR definition of software at ITAR § 120.45(f), as follows:

> §120.45 End-items, components, accessories, attachments, parts, firmware, software, systems, and equipment.
>
> …
>
> (f) Software includes but is not limited to the system functional design, logic flow, algorithms, application programs, operating systems, and support software for design, implementation, test, operation, diagnosis and repair. A person who intends to export only software should, unless it is specifically enumerated in §121.1 of this subchapter (e.g., USML Category XIII(b)), apply for a technical data license pursuant to part 125 of this subchapter. **Software that converts a defense article into an item described in the EAR or an item described in the EAR into a defense article is directly related to the defense article. When a defense article has been converted into an item described in the EAR through software, the presence of the software that prevents the item from meeting or exceeding a USML control parameter does not make the item subject to the ITAR.**

Are the Reverse Implications for USML Category IX Intended and Correct?

97. Paragraph C of Note 2 to paragraph (f) states:

> **EO/IR simulation or projection system software that replicates via simulation either the output data or information provided by any article controlled in this category, a radiometrically calibrated spectral signature**

of any article controlled in this subchapter, volumetric effects of plumes or military operational obscurants, or countermeasure effects.

98. USML Category IX, generally, covers military training equipment and training, and, more specifically, its lists include: targets having an infrared signature that mimics a specific defense article, other item, or person; infrared scene generators; certain simulators and; software and associated databases not elsewhere enumerated on the USML used to model or simulate certain trainers, battle management, military test scenarios/models, or effects of weapons enumerated on the USML.

99. The reverse implication of paragraph C of Note 2 to paragraph (f) is that, in order to avoid significant overlap, DDTC intends to significantly descope USML Category IX.

100. While in the framework of ECR, generally, DDTC has committed to rewrite of USML Category XIII(a) commensurate with the final issuance of USML Cat. XII, the overall impact of the final issuance of USML Cat. XII to the rest of the USML is less well-advertised.

101. Does DDTC intend to significantly descope USML Category IX at the time of final issuance of USML Cat. XII in order to reconcile the significant overlap brought about by paragraph C of Note 2 to paragraph (f)?

102. My recommendation is to migrate the substance of paragraph C of Note 2 to paragraph (f) to USML Category IX, as follows:

Category IX—Military Training Equipment and Training

…

(b) Simulators, as follows:

…

(2)~~-(3)~~ [Reserved]

(3) EO/IR simulation or projection system software and associated databases that replicate via simulation:

(i) the output data or information provided by any article controlled in USML Category XII;

(ii) a radiometrically calibrated spectral signature of any article controlled in this subchapter; or

(iii) volumetric effects of plumes or military operational obscurants or countermeasure effects; or
…
(e) Technical data (see §120.10 of this subchapter) and defense services (see §120.9 of this subchapter):
…
(2) Directly related to the software and associated databases enumerated in paragraph**s (b)(3) and** (b)(4) of this category even if no defense articles are used or transferred; or

Are the Reverse Implications for "Defense Services" and "Software" Intended and Correct?

103. Note 3 to paragraph (f) states:
Technology for incorporating or integrating IRFPAs into permanent encapsulated sensor assemblies subject to the EAR, or integrating such assemblies into an item subject to the EAR, and integrating IITs into an item subject to the EAR, including integrating items subject to the EAR into foreign military commodities outside the United States, is subject to the EAR.

104. The ITAR does not define "technology" in ITAR § 120.10.

105. "Technology" is defined in Part 772 of the EAR as:
Specific information necessary for the "development", "production", or "use" of a product. The information takes the form of "technical data" or "technical assistance". Controlled "technology" is defined in the General Technology Note and in the Commerce Control List (Supplement No. 1 to part 774 of the EAR). "Technology" also is specific information necessary for any of the following: operation, installation (including on-site installation), maintenance (checking), repair, overhaul, refurbishing, or other terms specified in ECCNs on the CCL that control "technology."

N.B.: Technical assistance--May take forms such as instruction, skills training, working knowledge, consulting services.

NOTE 1: "Technical assistance" may involve transfer of "technical data".

NOTE 2: "Technology" not elsewhere specified on the CCL is designated as EAR99, unless the "technology" is subject to the exclusive jurisdiction of another U.S. Government agency (see § 734.3(b)(1)) or is otherwise not

> ***subject to the EAR (see § 734.4(b)(2)* [sic] *and (b)(3) and §§ 734.7 through 734.11 of the EAR).***
> [italics in original].

106. The Bureau of Industry and Security, Department of Commerce (BIS) has stated that the "EAR does not control services" (see Exhibit 1).

107. The definition of "technology" in the EAR includes references to "technical assistance," and it is plausible that "technical assistance" under the EAR may be confused with providing a service (see ITAR § 120.9) under the ITAR, but the definitions of "technical assistance" in the EAR and "defense service" in the ITAR are not aligned.

108. Under the EAR, it is important to recognize that "technical assistance," according to the EAR definition of "technology," is a form of information (the second sentence of the EAR's definition of "technology is: "**The information takes the form of 'technical data' or 'technical assistance'"**).

109. "Technical data" is defined in Part 772 of the EAR as certain types of information, as follows:

> **May take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories.**

110. But the EAR definition of "technical data" does not necessarily encompass all forms of EAR-controlled information.

111. EAR-controlled information may extend beyond the EAR definition of "technical data" to all information which is not: 1) either subject to the exclusive jurisdiction of another U.S. Government agency, or; 2) publicly available (see Part 772 of the EAR, Note 2 to the definition of "technology" and Part 734.3(b)(2) and (b)(3)).

112. As such, "technology" as defined in the EAR does not necessarily capture services which do not convey information, and the clarification from BIS states clearly that it does not.

113. On the other hand, the ITAR does not require furnishing of any information in order for a “defense service” to occur (see ITAR § 120.9(a)(1)).

114. It is also worth noting that the EAR definitions of “technology,” “technical assistance,” and “technical data” do not include software, whereas the ITAR definition of “technical data” (see ITAR § 120.10(a)(4)) includes software.

115. As such, by using the term “technology” in Note 3 to paragraph (f), and applying the definition of “technology” in the EAR (because the ITAR does not define “technology”), the reverse implication is that Note 3 to paragraph (f) does not exclude from ITAR jurisdiction pure services or software.

116. By using the term “technology” in Note 3 to paragraph (f), does DDTC intend to retain jurisdiction over pure services and software?

117. I do not believe DDTC intended to retain jurisdiction over pure services and software by virtue of its use of the term “technology” in Note 3 to paragraph (f).

118. In partial summary, Note 3 to paragraph (f) also states that technology **for integrating** permanent encapsulated sensor assemblies subject to the EAR into an item subject to the EAR is subject to the EAR.

119. To restate it in even simpler terms, it says that technology for integrating a certain EAR item into another certain EAR item is subject to the EAR.

120. A reverse implication is that technology for integrating other EAR items into other EAR items is subject to the ITAR.

121. Also, to provide contrast, Note 3 to paragraph (f) also states that technology **for incorporating or integrating** IRFPAs into permanent encapsulated sensor assemblies subject to the EAR is subject to the EAR.

122. Another reverse implication is that technology for **incorporating** permanent encapsulated sensor assemblies subject to the EAR into an item subject to the EAR is subject to the ITAR.

123. Did DDTC intend to imply that technology for integrating EAR items into EAR items is ever subject to the ITAR?

124. If not, why did DDTC include this provision in Note 3 to paragraph (f)?

125. I do not believe DDTC intended to imply this absurd result.

126. I also believe it is unnecessary to state in any note to any USML category that technology for integrating EAR items together is subject to the EAR.

127. Did DDTC intend to imply that technology for incorporating permanent encapsulated sensor assemblies subject to the EAR into an item subject to the EAR is subject to the ITAR?

128. If not, why did DDTC couch technology in terms of “incorporating or integrating” only with respect to IRFPAs going into permanent encapsulated sensor assemblies subject to the EAR?

129. Did DDTC intend to imply that all other activity related to having IRFPAs in permanent encapsulated sensor assemblies subject to the EAR, such as maintenance and repair, is subject to the ITAR?

130. If not, why did DDTC couch technology only in terms of “incorporating or integrating” as subject to the EAR?

131. I believe that DDTC has fallen victim to drafting carve-outs against the background of broad regulatory language.

132. As such, my recommendation is to broaden the language to encompass lifecycle support with respect to the products, as further described below.

133. Also in partial summary, Note 3 to paragraph (f) also states that integrating items subject to the EAR into foreign military commodities outside the US is subject to the EAR.

134. The ITAR does not define the terms “foreign military commodities” or “military commodity” in ITAR § 120.10.

135. The EAR defines the term “military commodity” in Part 772 of the EAR as:
An article, material, or supply that is described on the U.S. Munitions List (22 CFR Part 121) or on the Munitions List that is published by the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, but does not include software, technology and any item listed in any ECCN for which the last three numerals are 018 or any item in the “600 series.”

136. In the EAR’s Commerce Control List (CCL) at Part 774, ECCN 0A919 describes EAR-controlled military commodities as military commodities produced and located outside the United States which are not subject to the ITAR, and which either: 1) incorporate certain cameras; 2) incorporate more than a certain amount of US-origin 600 series content, or; 3) are direct products of US-origin 600 series technology or software.

137. I believe it is fair to characterize ECCN 0A919 as describing “foreign military commodities.”

138. ECCN 0A919 currently contains a Related Controls description which states:
(1) “Military commodities” are subject to the export licensing jurisdiction of the Department of State if they incorporate items that are subject to the International Traffic in Arms Regulations (ITAR) (22 CFR Parts 120 - 130). (2) “Military commodities” described in this paragraph are subject to the export licensing jurisdiction of the Department of State if such commodities are described on the U.S. Munitions List (22 CFR Part 121) and are in the United States. (3) The furnishing of assistance (including training) to foreign persons, whether in the United States or abroad, in the design, development, engineering, manufacture, production, assembly, testing, repair, maintenance, modification, operation, demilitarization, destruction, processing, or use of defense articles that are subject to the ITAR [sic]; or the furnishing to foreign persons of any technical data controlled under 22 CFR 121.1 whether in the United States or abroad are

> **under the licensing jurisdiction of the Department of State. (4) Brokering activities (as defined in 22 CFR 129) of "military commodities" that are subject to the ITAR are under the licensing jurisdiction of the Department of State.**

139. Of note, the above-referenced Related Controls paragraph has a circular reference with respect ECCN 0A919.a.1, and should more appropriately state "destruction, processing, or use of defense articles described on the U.S. Munitions List"; otherwise the Related Controls paragraph might suggest that DDTC has ceded controls over defense services to BIS, which is not likely because the EAR does not control services (see Line 106, above and Exhibit 1).

140. The EAR has no entry for a corresponding control for "technology" at what would be, presumably, ECCN 0E919.

141. As such, a reverse implication of Note 3 to paragraph (f) is that DDTC only intends to maintain jurisdiction over information related to the integration of EAR-controlled items into US-origin defense articles worldwide and all defense articles, regardless of origin, when those defense articles are in the US.

142. I believe this is a bad idea, but have nevertheless attempted to implement it in my recommend rewrite of the principle, as further described below.

143. Another reverse implication of Note 3 to paragraph (f) is that DDTC intends to maintain jurisdiction over pure services and software, even those related to the integration of EAR-controlled items into foreign military commodities outside the US.

144. I do not believe this was DDTC's intent in using the term "technology."

145. I believe DDTC intended to shift jurisdiction of certain services and technical data to the EAR.

146. As such, my recommendation includes adding verbiage to both the ITAR definitions of technical data at ITAR § 120.10 and defense service at ITAR § 120.9.

147. And another reverse implication of Note 3 to paragraph (f) is that DDTC intends to maintain jurisdiction over all other technology, including that for incorporating into and maintenance and repair of EAR-controlled items in foreign military commodities outside the US.

148. I do not believe this was the intended result of Note 3 to paragraph (f), as discussed herein above and as further described below.

149. Should such a significant proclamation impacting the ITAR definition of technical data (and perhaps even defense services) appear in a paragraph to a note in a single USML category?

150. I recommend the principle be implemented via modification to the ITAR definitions of technical data at ITAR § 120.10 and defense service at ITAR § 120.9.

151. Moreover, is it the intent of DDTC to, on the one hand, maintain ITAR control over some technology (e.g., integration of EAR-controlled items into US-origin defense articles), but release closely related technology (e.g., integration of EAR-controlled items into foreign military commodities) all the way to classification under the EAR as EAR99?

152. As already stated herein, I believe this is a bad idea, but I nevertheless attempt to provide clearer language to bring it into effect via modification to the ITAR definitions of technical data at ITAR § 120.10 and defense service at ITAR § 120.9.

153. As such, I recommend Note 3 to paragraph (f) by implemented via modification to the ITAR definitions of technical data at ITAR § 120.10 and defense service at ITAR § 120.9 as follows:

> §120.9 Defense service.
>
> (a) Defense service means:
>
> (1) The furnishing of assistance (including training) to foreign persons, whether in the United States or abroad in the design, development, engineering, manufacture, production, assembly, testing, repair, maintenance, modification, operation, demilitarization, destruction, processing or use of defense articles;
>
> …

(b) ~~[Reserved]~~ **The definition in paragraph (a) of this section does not include:**

(1) The furnishing of assistance to foreign persons directly related to the entire lifecycle for:

(i) infrared focal plane array (IRFPA) in permanent encapsulated sensor assemblies described in the EAR;

(ii) image intensifier tubes (IITs) in an item described in the EAR; or

(iii) items subject to the EAR in items described in ECCN 0A919.

…

§120.10 Technical data.

(a) Technical data means, for purposes of this subchapter:

(1) Information, other than software as defined in §120.10(a)(4), which is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles. This includes information in the form of blueprints, drawings, photographs, plans, instructions or documentation.

…

(b) The definition in paragraph (a) of this section does not include**:**

…

(5) provided such information does not include design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters), information directly related to the entire lifecycle for:

(i) IRFPA in permanent encapsulated sensor assemblies described in the EAR; or

(ii) image intensifier tubes (IITs) in an item described in the EAR; or

(6) information directly related to the entire lifecycle for items subject to the EAR in items described in ECCN 0A919; or…

RECOMMENDATIONS

154. Please consider the above-described and following recommended revisions (recommended additions in **bold red font**; deletions in ~~blue strikethrough font~~) for not only USML Cat. XII, but also, as applicable, for other parts of the ITAR.

§120.9 Defense service.

(a) Defense service means:

(1) The furnishing of assistance (including training) to foreign persons, whether in the United States or abroad in the design, development, engineering, manufacture, production, assembly, testing, repair, maintenance, modification, operation, demilitarization, destruction, processing or use of defense articles;

…

(b) ~~[Reserved]~~ **The definition in paragraph (a) of this section does not include:**

(1) The furnishing of assistance to foreign persons directly related to the entire lifecycle for:

(i) infrared focal plane array (IRFPA) in permanent encapsulated sensor assemblies described in the EAR;

(ii) image intensifier tubes (IITs) in an item described in the EAR; or

(iii) items subject to the EAR in items described in ECCN 0A919.

…

§120.10 Technical data.

(a) Technical data means, for purposes of this subchapter:

(1) Information, other than software as defined in §120.10(a)(4), which is required for the design, development, production, manufacture, assembly, operation, repair, testing, maintenance or modification of defense articles. This includes information in the form of blueprints, drawings, photographs, plans, instructions or documentation.

…

(b) The definition in paragraph (a) of this section does not include**:**

(1) information concerning general scientific, mathematical, or engineering principles commonly taught in schools, colleges, and universities**;**~~, or~~

(2) information in the public domain as defined in §120.11 of this subchapter**;** ~~or~~

(3) telemetry data as defined in note 3 to Category XV(f) of part 121 of this subchapter**;**~~.~~

(4) provided such information does not include design methodology, engineering analysis, or manufacturing know-how for an infrared focal plane array (IRFPA) in Category XII of part 121 of this subchapter, information directly related to the entire lifecycle for:

(i) IRFPAs in higher-level packaged assemblies not in Category XII of part 121 of this subchapter; or

(ii) external interface control documentation for higher-level packaged assemblies not in Category XII of part 121 of this subchapter; or

(5) provided such information does not include design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters), information directly related to the entire lifecycle for:

(i) IRFPA in permanent encapsulated sensor assemblies described in the EAR; or

(ii) image intensifier tubes (IITs) in an item described in the EAR; or

(6) information directly related to the entire lifecycle for items subject to the EAR in items described in ECCN 0A919; or

~~It also does not include~~**(7)** basic marketing information on function or purpose or general system descriptions of defense articles.

…

§120.45 End-items, components, accessories, attachments, parts, firmware, software, systems, and equipment.

…

(f) Software includes but is not limited to the system functional design, logic flow, algorithms, application programs, operating systems, and support software for design, implementation, test, operation, diagnosis and repair. A person who intends to export only software should, unless it is specifically enumerated in §121.1 of this subchapter (e.g., USML Category XIII(b)), apply for a technical data license pursuant to part 125 of this subchapter. **Software that converts a defense article into an item described in the EAR or an item described in the EAR into a defense article is directly related to the defense article. When a defense article has been converted into an item described in the EAR through software, the presence of the software that prevents the item from meeting or exceeding a USML control parameter does not make the item subject to the ITAR.**

Category description:

Category IX—Military Training Equipment and Training
…
(b) Simulators, as follows:
…
(2) ~~(3)~~ [Reserved]

(3) EO/IR simulation or projection system software and associated databases that replicate via simulation:

(i) the output data or information provided by any article controlled in USML Category XII;

(ii) a radiometrically calibrated spectral signature of any article controlled in this subchapter; or

(iii) volumetric effects of plumes or military operational obscurants or countermeasure effects; or
…
(e) Technical data (see §120.10 of this subchapter) and defense services (see §120.9 of this subchapter):
…
(2) Directly related to the software and associated databases enumerated in paragraph**s (b)(3) and** (b)(4) of this category even if no defense articles are used or transferred; or
…
USML Cat. XII:

*(f)**(1)** Technical data (as defined in § 120.10 of this subchapter) **specially designed for** and defense services (as defined in § 120.9 of this subchapter) directly related to the defense articles enumerated in paragraphs (a) through (e) of this category. (See § 125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)

(2) Technical data (as defined in § 120.10 of this subchapter) directly related to the defense articles enumerated in paragraphs (c)(1), (c)(2), (c)(9) or (e)(3)-(5) of

this category. (See § 125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)

~~**Note 1 to paragraph (f):** Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.~~

~~**Note 2 to paragraph (f):** Software and technical data include:~~

~~A. Design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters) for lasers described in paragraphs (b)(6) and (b)(9) through (13) of this category, IITs controlled in paragraph (c)(1) of this category and their parts and components controlled in paragraph (e)(2) of this category (including tube sealing techniques, interface techniques within the vacuum space for photocathodes, microchannel plates, phosphor screens, input glass-window faceplates, input or output fiber optics (e.g., inverter)), IRFPAs and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating structures for an IRFPA and detector elements therefor controlled in paragraph (c)(2) or structures for ROICs controlled in paragraph (e)(4) or (5) of this category, and specially designed ROICs controlled in paragraphs (e)(4) and (5) of this category (including bonding or mating (e.g., hybridization of IRFPA detectors and ROICs), prediction or optimization of IRFPAs or ROICs at cryogenic temperatures, junction formation, passivation).~~

~~**Note to paragraph A of note 2 to paragraph (f):** Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.~~

~~B. Software that converts an article controlled in this category into an item subject to the EAR or an item subject to the EAR into an article controlled in this category is directly related to the defense article controlled in this category. When a defense article has been converted into an item subject to the EAR through software, the presence of the software that prevents the item from meeting or exceeding a USML control parameter does not make the item subject to the ITAR.~~

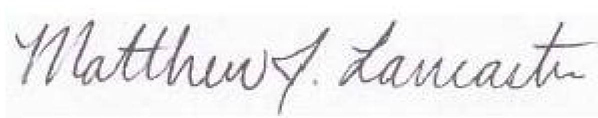
~~C. EO/IR simulation or projection system software that replicates via simulation either the output data or information provided by any article controlled in this category, a radiometrically calibrated spectral signature of any article controlled in this subchapter, volumetric effects of plumes or military operational obscurants, or countermeasure effects.~~

~~Note 3 to paragraph (f): Technology for incorporating or integrating IRFPAs into permanent encapsulated sensor assemblies subject to the EAR, or integrating such assemblies into an item subject to the EAR, and integrating IITs into an item subject to the EAR, including integrating items subject to the EAR into foreign military commodities outside the United States, is subject to the EAR.~~

…

Category XIII— Materials and Miscellaneous Articles

(a) ~~Cameras and specialized processing equipment therefor, photointerpretation, stereoscopic plotting, and photogrammetry equipment which are specifically designed, developed, modified, adapted, or configured for military purposes, and components specifically designed or modified therefor.~~ **[Reserved]**



Matthew J. Lancaster
PRIVATE CITIZEN

May 27, 2015

Exhibit 1

From: [redacted]
To: Matthew Lancaster
Subject: RE: BETA Site Advisory Opinion Request
Date: Wednesday, February 04, 2015 9:26:07 AM

Hello Matthew,
I have imbedded my response and comments in the email below with //.

Please let me know if you have any questions.

[redacted]
U.S. Department of Commerce
[redacted]
[redacted]@bis.doc.gov

-----Original Message-----
From: Matthew Lancaster [redacted]
Sent: Monday, February 02, 2015 4:31 PM
To: [redacted]
Subject: RE: BETA Site Advisory Opinion Request

Good Afternoon [redacted]

Thank you for taking the time with me on the phone today to ensure I understood the guidance provided below. It was very helpful.

During our discussion, our focus turned to Software-as-a-Service (SaaS) hosted by a cloud-based storefront. I asserted that while the BIS Advisory Opinion dated November 13, 2014 (the "Cloud Store AO") was helpful for owners of cloud-based storefronts, I had concerns that the Cloud Store AO did not necessarily mean that companies providing SaaS to the cloud-based storefront provider (e.g. [redacted]) fell within the transaction described. In other words, I opined that a company, like [redacted], providing SaaS, like [redacted] for, say, [redacted], to sell through [redacted] cloud-based storefronts had export obligations because [redacted] would have knowledge that [redacted] intended to make [redacted] available worldwide through the [redacted] cloud-based storefront. You commented that this might not be the case, since, in this scenario, the transaction between [redacted] and [redacted] occurs wholly within the US, so there is no export. Thereafter, [redacted] is not exporting [redacted] per the Cloud Store AO.

I found this perspective compelling.

//The EAR does not control services. In this case there is no export of software to the end user or [redacted] in the U.S. There was guidance given in the cloud computing advisory opinion of 1/13/2009. In your company's scenario there could be a potential export taking place when the software to be hosted is sent to [redacted]. If [redacted] will host it on servers located outside of the U.S., then there would be an export to [redacted] server hosting location(s).

We then discussed the fact that some SaaS, like [redacted], is time-bombed. Users get a free trial period after which a subscription must be purchased in order to continue to access [redacted]. When an [redacted] user chooses to subscribe, [redacted] collects information on the user. If at that time the user identifies himself with an address in a proscribed destination, what obligations does [redacted] have to block the user's access to:
1) future access to any [redacted] SaaS (including free content); and,
2) current and future access to [redacted] premium products?

In other words, in this no-export-has-happened environment of cloud-based storefronts, must [redacted] refuse service to an individual who identifies himself with an address in a proscribed destination (e.g., Cuba) until [redacted] obtains an export license?

//This is still a cloud based service. There is no export to the end users. Before and after the trail expires, there is no export of the software to the end user, therefore, no controllable export.

//But I want to address the scenario if there were to be an export of software to the end user. We issued an advisory opinion on October 24, 2013 regarding time restricted EAR99 software posted online. Please review. It says the act of posting software on the internet where it can be downloaded by anyone does not establish "knowledge" of a prohibited export or reexport nor triggers any "red flags" necessitating the affirmative duty to inquire under the "Know your Customer" guidance provided in the EAR. It goes on to address IP address collection by saying a violation would not occur if the IP address of the person downloading the software is collected by the software provider at the time of download and stored as a "footprint" in the machine code of the software provider's data base, BUT is not tracked or used for any purpose by the software provider.

//I consulted my director who signed these advisory opinions. She agreed with this assessment for EAR99 software such as yours.

//Bottom line is if you are making yourself aware of the end users then you have "knowledge" to do something, but you are not obligated by the EAR to make yourself aware.

And, what happens, if anything, to [redacted] obligations if the user is still within the trial period, but chooses to voluntarily identify himself by completing his user profile, indicating an address in a proscribed destination? What if he completes this user profile before the trial period is initiated (must he, at that point, be banned from the chat rooms - or should we keep him out of the discussion from the very beginning by maintaining screens against IP addresses)?

//As stated above, since this is a SaaS, if there is no export then the question is moot. However, you may want to contact Office of Foreign Asset Controls at the Dept. of Treasury. I believe they cover services to the embargoed countries.

//However, going to the scenario if there is an export of software to the end user, then at the time of export there was no "knowledge" then there is no violation even if during the trial period you obtain "knowledge" because of a voluntary disclosure by the end user. But there would be basis for blocking the subscription use after the 30 day period was over. The EAR does not obligate you to block them from chat rooms (chatting online would not be an export). If, hypothetically the same end user wanted to download another free trial of some other software offering your company made available for free and anonymous download then you would not have "knowledge" of it. In other words, you are not obligated to find the end user and block them for software exports you make free and anonymous.

Thank you for both your time and consideration regarding these questions and scenarios. As discussed on the phone, to date we've been very conservative, and I don't want to recommend we drop any existing shields if to do so would run contrary to the intent of the US regulators.

Best Regards,
Matthew J. Lancaster [redacted]

-----Original Message-----
From: [redacted]@bis.doc.gov]
Sent: Tuesday, January 27, 2015 10:22 AM
To: Matthew Lancaster

Phone:....[redacted]

Message:.....[redacted] seeks advice for three (3) questions:

1) Given Note 4 to Category 5, Part 2 to Supplement 1 to Part 774 (the "CCL"), are [redacted] books which come with compact disks (CDs) "published" within the meaning of EAR Part 734.7, and, as such, insofar as provided in accordance with EAR Part 724.7(b), outside the scope of the EAR in accordance with EAR Part 734.3(b)(3)?

// The book itself would certainly be public but if there is software on the CD then there could be something of control.

2) Does Note 4 to Category 5, Part 2 to the CCL (hereinafter referred to as "Note 4") extend to evaluation versions of software when the full version definitively qualifies for exclusion by operation of Note 4?

//Yes, note 4 would apply to time bombed software but the publicly available provisions do not apply to trial version that expire. This is a restriction on the use of the software which is against publicly available.

3) Is standalone software and Software-as-a-Service capability (SaaS) publicly available if readily available at one or more libraries open to the public or university libraries after having been made available to such libraries at a price which is not intended to exceed the cost of reproduction and distribution?

// I have not heard of this method of making software publicly available because it usually applies to information found in libraries, not executable software. For example, the library may have a copy of [redacted] that was given to them for users to use for their word processing needs. This would not mean that [redacted] is publicly available. It is, however, mass market software. The test would be if someone could legally (without breaking a license agreement) have a copy of the software from the library for their unrestricted use.

In CCATS [redacted], BIS determined that some of [redacted] software, including [redacted] classifies for export from the US as EAR99 - based, we believe, largely on Note 4, which excludes an item that incorporates or uses 'cryptography' from Category 5, Part 2 controls if the item's primary function or set of functions is not 'information security', including "applied geosciences – mining / drilling, atmospheric sampling / weather monitoring, mapping / surveying, dams / hydrology" (see http://www.bis.doc.gov/index.php/policy-guidance/encryption/encryption-faqs#15).

[redacted] believes that earlier versions of [redacted] are also excluded from Category 5, Part 2 controls, including, very likely, evaluation copies of the same.

[redacted] publishes books about the science, application, and technology of geographic information systems (GIS). One such book, for example, which is entitled [redacted], comes with two compact disks. One has a fully functional copy of [redacted] software that expires 180 days after installation; the other has exercise data which does not expire. The exercise data is used in conjunction with exercise chapters, which each contain two to four exercises showing how to accomplish a particular GIS task in a realistic context, such as symbolizing and labeling maps, querying maps, and geocoding addresses.

According to [redacted] is available at over 500 libraries (see [redacted]). Many other [redacted] books and [redacted] products can also be found by executing a search in [redacted].

[redacted] seeks formal guidance from BIS to confirm our conclusion that if an item is:
1) excluded from Category 5, Part 2 of the CCL by operation of Note 4 to the same, and;

//Yes, [redacted] is Note 4 software.

2) readily available at one or more libraries open to the public or university libraries after having been made available to such libraries either for free or at a price that does not exceed the cost of reproduction and distribution - then the item is published within the meaning of EAR Part 734.7 and outside the scope of the EAR in accordance

Subject: FW: BETA Site Advisory Opinion Request

Hello Matthew,
I have tried to answer your questions below. My answers are marked with a //. Please let me know if you have any questions. I am available tomorrow by phone, if needed.

[redacted]
U.S. Department of Commerce
[redacted]@bis.doc.gov

-----Original Message-----
From: [redacted]
Sent: Thursday, January 22, 2015 10:12 AM
To: [redacted]
Subject: FW: BETA Site Advisory Opinion Request

Good morning, [redacted]

Would one of you like to respond to this???

Thanks
[redacted]
U.S. Department of Commerce
Bureau of Industry and Security
[redacted]@bis.doc.gov
www.bis.doc.gov

-----Original Message-----
From: BIS Website [mailto:web_site@bis.doc.gov]
Sent: Wednesday, January 21, 2015 8:45 PM
To: REGPolicyWeb
Subject: BETA Site Advisory Opinion Request

You have a new submission.

First Name:....Matthew

Last Name:.....Lancaster

Email:.....[redacted]

with EAR Part 734.3(b)(3).

//it appears that the offered software does have restrictions on it, in that it is a trial version. It would not be considered published if there is a time restriction on the use of it.

Furthermore, [redacted] seeks BIS concurrence with respect to our application of Note 4 to evaluation copies of software (especially where the full version of the software definitively falls within the Note 4 exclusion).

//Yes, Note 4 can apply to the trial version.

Finally, [redacted] has a strong tradition of supporting libraries and schools by striving to provide our products and services to such institutions at a price which does not exceed the cost of reproduction and distribution. As such, for example, [redacted] software is available at [redacted] and [redacted] (see [redacted]). Given Note 4 applicability, and given further the availability of software at one or more libraries open to the public or university libraries, and that [redacted] strives to make such software available to such institutions at a price which does not exceed the cost of reproduction and distribution, [redacted] believes that such software is outside the scope of the EAR pursuant to EAR Part 734.3(b)(3). Furthermore, under these same conditions, [redacted] believes this to be the case even with respect to SaaS. [redacted] seeks BIS confirmation of these position for software and SaaS as well.

// Making copies available at university libraries is not available to anyone. For one, the general public does not have access to university libraries and computers. Those are software licenses available to students. If the full software is made available for anyone to download online or take from public libraries then it could be considered public. The library method of making software publicly available is less heard of since you can reach a much wider audience online.

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226 Golden Gate Point, Suite 61
Sarasota, FL 34236
941-203-5158, Fax 267-295-8787
www.maxtech-intl.com

U.S. Department of State
Directorate of Defense Trade Controls (DDTC)

Re: **Revision of U.S. Munitions List Category XII**

Dear Madam/Sir,

I am writing to comment on the proposed Category XII Revision. My comments will pertain mainly to cooled and uncooled infrared detectors and cores.

My company, Maxtech International, has specialized in analyzing worldwide infrared markets for over 25 years. We regularly make site visits to all suppliers of infrared detectors worldwide and publish a series of market research reports on commercial, dual-use and military infrared markets. These reports have been purchased by all major suppliers of infrared detectors and systems, as well as the U.S. Army. In addition, we have carried out a major capabilities analysis of infrared detector manufacturers for the U.S. Air Force. We also publish the newsletter *Infrared Imaging News* which is widely regarded as the most authoritative source of information in this field and is read at the Night Vision and Electronic Sensors Directorate (NVESD) and SOCOM (Special Operations Command).

We are not affiliated with any company and are thus in a unique position to provide an independent viewpoint.

I would like to restrict my comments to paragraphs (c) and (e) of Category XII:

(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores. (and its subsection)

(e) (7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components (and its subsections).

The items I will concentrate on have been underlined.

I believe that it is essential that the U.S. position of “owning the night” in infrared technology be preserved and that key technologies must be controlled and kept out of the hands of our enemies.

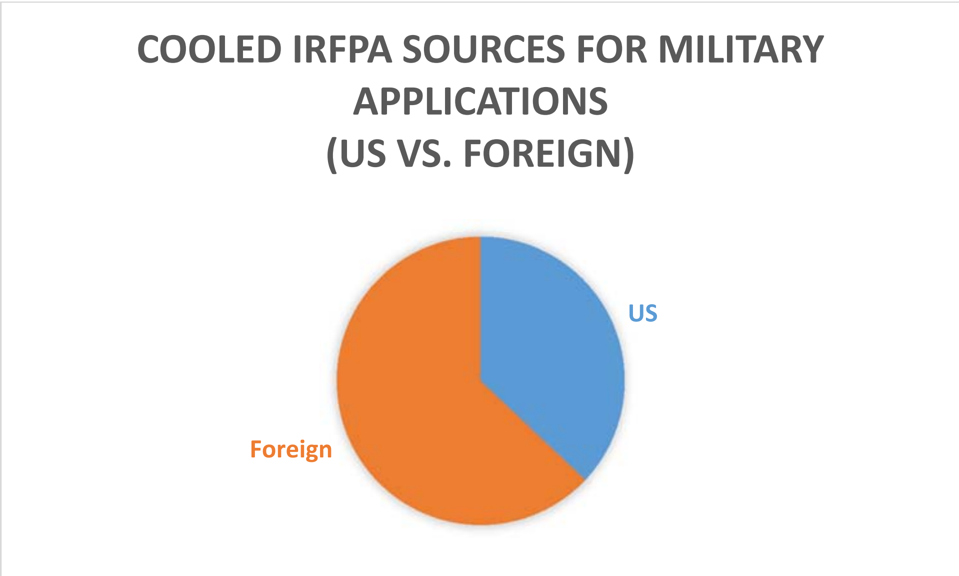
However, in controlling this technology we must recognize the significant foreign availability of infrared technology, much of which is advertised by foreign suppliers as “ITAR free.” Thus, by controlling too much, the U.S. prevents U.S. defense companies from competing in overseas markets and, in effect, weakens our infrared industrial base – which we rely on for our technological advantage against our adversaries.

I will comment separately on the cooled and uncooled IRFPAs because of their different roles.

COOLED IRFPAs

Chart 1 provides the current view (based on 2014 data) of Foreign Availability of cooled IRFPAs for military applications:

Chart 1

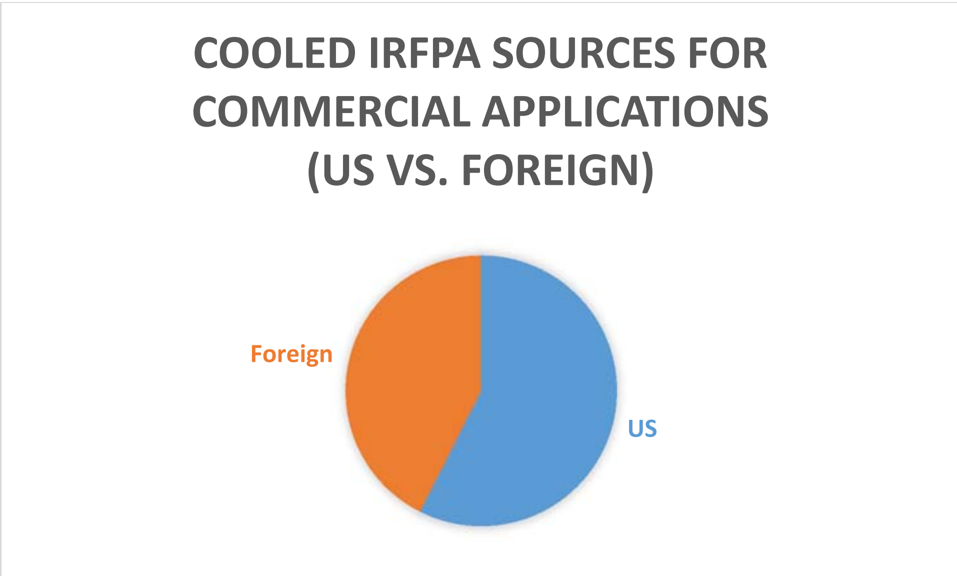


As can be seen, nearly two-thirds of Military IRFPAs consumed worldwide are made by foreign suppliers (mainly based in France, Israel, the UK and Germany, but also in Sweden, South Korea and China).

Furthermore, these foreign manufacturers do not supply lower performance IRFPAs and systems but rather leading edge products. I am attaching datasheets from two such products as an illustration (SCD Blackbird and Sofradir Daphnis). As further proof of the advanced nature of these foreign-sourced products, some of these cooled products by foreign suppliers are used in U.S. systems.

These cooled products manufactured by foreign suppliers are also available for commercial and dual-use applications. Chart 2 shows Foreign Availability for Commercial and Dual-Use Applications.

Chart 2



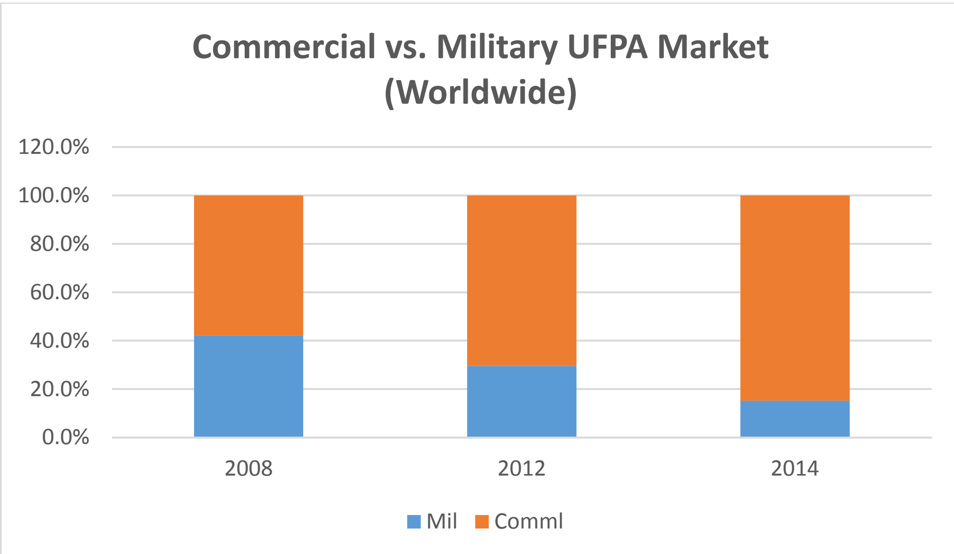
I.e. nearly half of all commercial and dual-use applications are being satisfied by Foreign suppliers of cooled IRFPAs.

It should be noted that Wassenaar controls Cooled IRFPAs as 6.A.2.a.3.c and "cooled camera cores" and integrated IRFPA dewar cooler assemblies (IDCA) as 6.A.3.b.4.a dual-use items. This is relevant to item 4) in the Request for Comments which states that the US Government does not want to inadvertently control items on the ITAR that are in normal commercial use. The Request for Comments also states that only items that provide the US with critical military or intelligence advance should be controlled by the ITAR. Since these items are controlled by the Wassenaar dual-use list they clearly are considered in normal commercial use and due to the volumes of the non-US manufacturers, these items are not unique to the US.

UNCOOLED IRFPAs

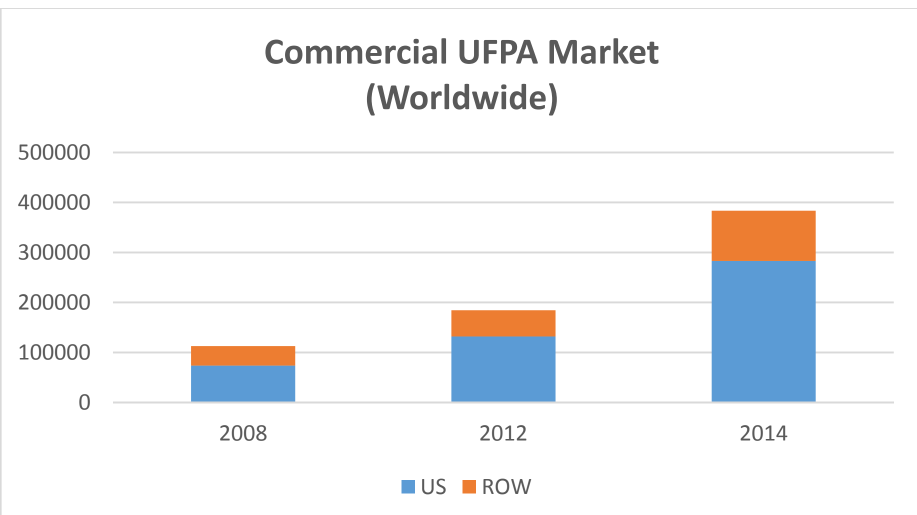
Uncooled FPAs (UFPAs) are important for both Commercial and Military applications. However, Commercial applications outnumber Military applications by 4 to 1 and the trend is continuing downward as shown in Chart 3.

Chart 3



The growth of the Commercial UFPA market (in units) is shown in Chart 4.

Chart 4



As can be seen, the growth of ROW (Rest of World) suppliers outside the U.S. has been significant.

The hold on the commercial uncooled market by U.S. UFPA suppliers is fragile, since foreign suppliers freely supply large format FPAs, with small pixel sizes and higher frame rates to customers worldwide. Please see the attached datasheets from three non-US UFPA manufacturers (Ulis of France, SCD of Israel and NEC of Japan) who supply such devices.

The listing below of UFPA suppliers worldwide, together with the technology used, provides a good overview of the extent of availability worldwide:

- Vanadium Oxide (VOx)
  - Five Companies in the U.S.
  - One in Japan
  - One in Israel
  - Two in China
  - Two in Canada
- Amorphous Silicon (a-Si)
  - One in France – ULIS is 2nd[d] Largest Volume Producer for All UFPAs World-Wide
  - One in U.S.
  - Two in China
  - One in Germany
- Silicon-on-Insulator (SOI)
  - Two in Japan
  - One in Korea
- Titanium Oxide (TiOx)
  - One in Korea
- Various Uncooled Technologies
  - China
  - Turkey
  - Korea

<u>Recommendations</u>:

The “bright line” to separate USML and CCL items is stated as the primary goal of export control reform. However, it needs better implementation.

In particular, references in the ITAR to cooled and uncooled FPAs and systems should be accompanied by “specially designed” in order to accurately identify military systems in paragraph (c) and components in paragraph (e).

Uncooled FPAs and cameras incorporating FPAs larger than the 328,000 elements outlined in (c)(5) should be exportable under CCL, since these are now widely available overseas.

Cooled FPAs, IDCAs, and Cameras should be controlled under the CCL in order to match the Wassenaar Dual-use List, and in consideration of world-wide availability, unless the items are specially designed for military applications.

These considerations are in the interest of protecting the U.S. industrial base for infrared components and systems which is increasingly in danger of being eclipsed by foreign availability.

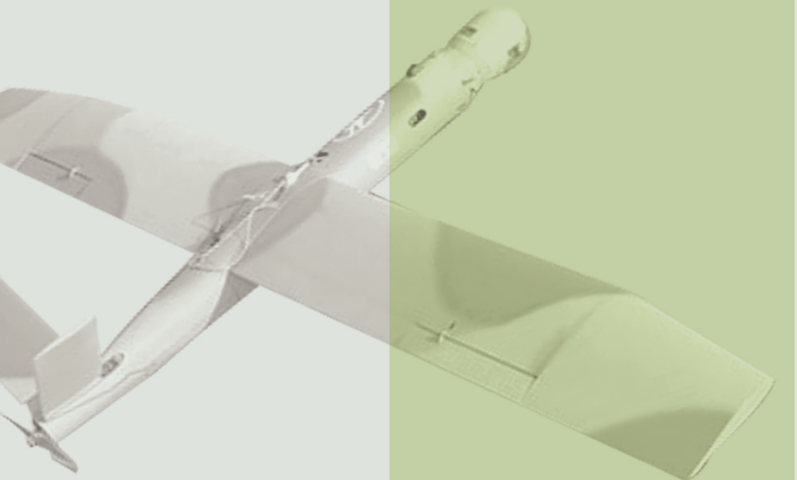
Thank you for providing this opportunity to comment on the proposed export regulations.

Sincerely,

Dr. Gabor F. Fulop
President
Maxtech International, Inc.

Attachments:
SCD Blackbird (1920x1536/10 InSb cooled IDCA)
Sofradir Daphnis HD (1280x720/10 MCT cooled IDCA
Ulis Pico 1024- 68 (1024x768/17 uncooled VOx FPA)
SCD Bird XGA (1024x768/17 uncooled VOx FPA)
NEC HX3220i 640x480/12 uncooled camera with 12 micron VOx microbolometer

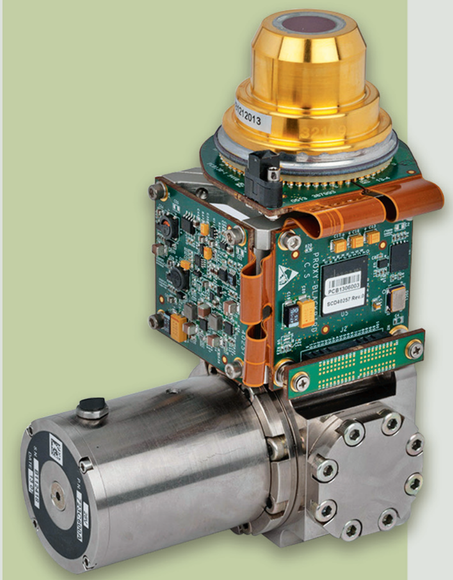
BLACKBIRD



MWIR InSb detector, 1920 x 1536 format, 10μm pitch, Digital ROIC

Description

BLACKBIRD is a state-of-the-art MWIR detector, which is an extension to the High Definition family of detectors at SCD. It includes a 3 Mega-pixel FPA in 1920x1536 pixels format and 10μm pitch. The new FPA is based on SCD's mature InSb technology and on a digital readout circuit implemented in advanced CMOS process. The FPA is very similar in size to SCD's SXGA format Hercules detector and can actually be packaged in the same Dewar. This yields a very large format detector with outstanding image quality, high frame rate, and relatively compact size.



Applications

- Persistent surveillance
- Long/medium range Surveillance & Targeting
- IRST
- MWS
- Thermography

Main Features

- High sensitivity: Low readout noise, Low dark current, High Quantum Efficiency
- Range of gain possibilities
- High frame rate: ≥ 90 Hz in full frame
- Simple electronic interface

SemiConductor Devices

Typical Performance

PARAMETER	TYPICAL VALUE
Detector type	InSb 2D array
FPA spectral range	1÷5.4 µm
Format	1920×1536
Pitch	10 µm
Integration modes	ITR, IWR, others
Integration capacitors and their Floor Noise (FN) *	0.4Me- ; FN = 60e-
	0.7Me- ; FN = 90e- (ITR mode only)
	2.5Me- ; FN = 370e-
	4.5Me- ; FN = 950e-
Maximum frame rate (full format, 4 video ports)	≥ 90 F/s
Video output	Digital output, 4 / 2 / 1 ports** (LVDS, 32:4 Channel link)
Digital signal resolution	13 bit
Readout mode	Normal / 2x2 Binning
Readout direction	Bottom-up / Left-Right
Windowing	Flexible: at 2 row steps
NETD (2.5Me- Cap.)	< 25mK at 70% well fill capacity
Local Residual Non Uniformity	0.04% STD/DR at 10-90% well fill capacity
IDCA optical parameters ***	F/3, spectral range: 3.6÷4.9 µm (defined by cold filter)
Cooler options	Full specification: 1W cooler Reduced specification (e.g. 1920×1080 format, 60Hz): 0.75W cooler
Dimensions (with Ricor K543 1W integral rotary cooler)	Weight – approx. 1.1Kg Length (optical axis) – 150 mm

* ITR and IWR modes are possible unless otherwise noted. Floor noise is specified in IWR mode. Floor noise in ITR mode expected to be equal or lower than IWR mode.

** Full frame output is enabled with 1, 2 or 4 video ports. Compared to 4 ports the 2 or 1 video ports enable lower power consumption while max. frame rate is reduced.

*** Other optical configurations are possible.

Specifications are subject to changes without further notice

SemiConductor Devices

SCD/UNC/41843-0313

• P.O. Box 2250, Haifa 31021 Israel • Tel: (+972)-4-9902535 9902500
• Fax: (+972)-4-9902627 • e-mail: marketing@scd.co.il • Web: www.scd.co.il

PRELIMINARY

DAPHNIS-HD MW

1280 x 720 - 10 µm pitch - MCT

HD 10 µm PITCH: THE BEST OFFER FOR COMPACT 16:9 FORMAT MWIR SYSTEMS

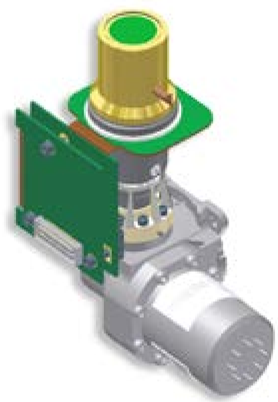
DAPHNIS-HD MW is the suitable product for all your applications requiring 16:9 HD format: airborne, naval, and ground vehicles.

This new innovation of the smallest pixel pitch from Sofradir guarantees:

- COMPACTNESS
- HIGH RESOLUTION
- LONGER RANGE
- LARGER FIELD OF VIEW
- IMPROVED RELIABILITY

DAPHNIS-HD MW takes full advantage of Sofradir latest HgCdTe technologies. It provides simplified interfaces for an easy and quick integration in your systems.

The proxy board offers management and correction of the detector as well as digital output.



ARRAY FEATURES

Format	1280 x 720
Pixel pitch	10 µm x 10 µm
Detector spectral response	3.4 µm – 4.9 µm
FPA Operating Temperature	110 K typical

ROIC (READ-OUT INTEGRATED CIRCUIT)

ROIC architecture	Digital outputs; Direct Injection input circuit
ROIC functionalities	Programmable integration time, anti-blooming, invert/revert; binning, snapshot operation, selectable read mode (IWR or ITR), programmable windowing
Charge Handling capacity	0.7 Me-, 2.2 Me-, 4.4 Me-

INPUT / OUTPUT

Board Power supply	$6V_{DC}$
Board Power dissipation	$1.5W_{DC}$ @20°C
Data processing	Bad Pixel Replacement (BPR) & Non Uniformity Correction (NUC)
Video output	14 bits, CAMERALINK®
Frame rate	Up to 100 Hz full frame rate

SOFRADIR-EC

PRELIMINARY

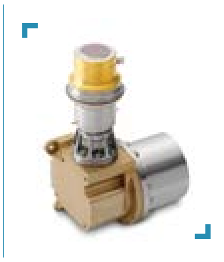
DAPHNIS-HD MW

1280 x 720 - 10 µm pitch - MCT

HD 10 µm PITCH: THE BEST OFFER FOR COMPACT 16:9 FORMAT MWIR SYSTEMS

DAPHNIS-HD MW






TYPICAL PERFORMANCES

Mean NETD	< 20 mK (293K, 50% well fill, 100 Hz)
Array operability	> 99.8%
Non uniformity	< 2.5% RMS (σ/mean, 293 K uncorrected performance)

	RM2	RM3	RM4	Split cooler
FOV	f/2; f/4	f/2; f/4	f/2; f/4	f/2; f/4
Cooler power supply	34 V	24 V	30 V	8-12 V
Regulated input power (*)	< 3.5 W_{AC}	< 4.5 W_{AC}	< 5 W_{AC}	< 8 W_{AC}
Cooldown input power (*)	< 12 W_{AC}	< 14 W_{AC}	< 15 W_{AC}	< 20 W_{AC}
Cooldown time	5 min	4 min	3 min	5 min
Cooler dimensions (mm)	Ø 30.5 × L 82	Ø 46 × L 71	Ø 43.5 × L 78	≤ Ø 45 × L 119
IDCA height (optical axis, mm)	H < 123.5	H < 144	H < 127	H < 112
Weight	< 0.45 kg	< 0.57 kg	< 0.57 kg	< 1.2 kg
Operating temperatures	– 40°C / + 71°C	– 40°C / + 71°C	– 40°C / + 71°C	– 40°C / + 71°C
Will depend on mission profile	10 000 h	12 000 h	18 000 h	40 000 h

(*) W_{AC} = at cooler pins AC input - W_{DC} = at cooler C&CE DC input

OPTIONS

- Technical training and support
- Cooler driving electronics

APPLICATIONS

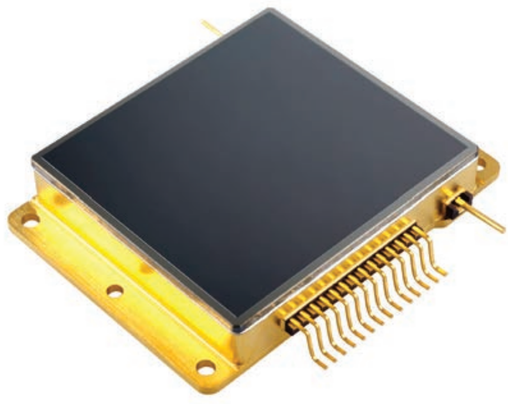
Technical characteristics described in this data sheet are for information only.
They are not contractual and may change without prior notice.

SOFRADIR EC, INC. 373 US Hwy 46W, Fairfield, NJ 07004 USA
Phone: 973-882-0211 Fax: 973-882-0997

SOFRADIR-EC
www.sofradir-ec.com

Thermal image sensors

17 µm



PICO1024-048

Pico*1024 Gen2* ™

1024 x 768

Military

Surveillance & Security

Thermography

ULIS
Infrared for you

www.ulis-ir.com

PICO1024-048

Pico1024 Gen2™

1024 x 768 - 17 µm

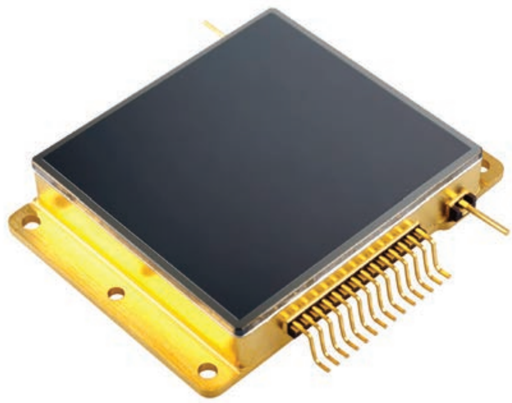
High performance, high definition infrared imaging

PERFORMANCE

- NETD < 50 mK (F/1, 300K, 30Hz)
- Frame rate up to 120Hz
- Typical array operability > 99.9%
- Low power consumption < 210 mW
- Extended operating temperature range: - 40°C to + 85°C
- Standards: MIL-STD-810 and -883
- Over exposure / Sun safe

FEATURES

- Material: resistive amorphous silicon
- Spectral response: 8 - 14 µm
- Readout configuration driven by serial link
- Overall dimension (mm): 41.2 x 30 x 6.6 pin out excluded
- Weight < 30 g
- Easy TEC-less implementation



- High resolution, high contrast imaging for long range detection
- Robust for extreme environments (e.g. TWS, RWS, situation awareness, UGS)
- Detects fast moving objects
- Reduced calibration time
- 24/7 surveillance capable
- Footprint compatible with UL05251-026

ULIS IN BRIEF

- A unique business model designed to serve OEMs
- High production capacity
- High-performance and cost-effective products
- Guaranteed product availability
- Customer partnership to assure success
- A dedicated customer support team

ULIS
Infrared for you

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BP 27 - 38113 Veurey-Voroize - France
Phone: +33 4 76 53 74 70 - Fax: +33 4 76 53 74 80
www.ulis-ir.com - ulis@ulis-ir.com

ELS-02-2015/01

BUREAU VERITAS
ISO 9001
ISO 14001
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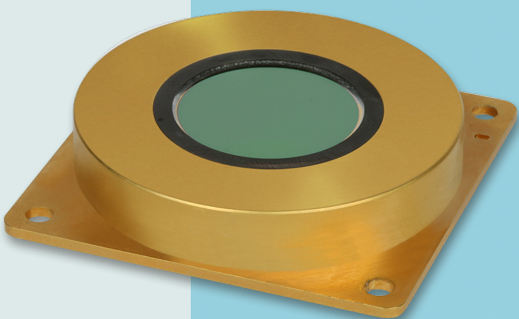
Groupe SOFRADIR

BIRD XGA



1024 x 768, 17µm pixel pitch VOx Microbolometer

Description

Bird XGA is a large format of uncooled LW IR detector, specially designed to address high-end, high performance applications. The detector ROIC integrates a low-noise high sensitivity and wide dynamic range.

Bird XGA is enhanced with the cutting edge Vanadium-Oxide technology, thus providing the ultimate sensor device for both military and civil applications.

Applications

- Thermal gun site
- Long-range surveillance systems
- Missile's applications
- Remote weapon station
- Long-range flame detection
- Driver's night-vision systems
- EO/IR tactical payloads

Main Features

- Vanadium Oxide technology
- Uncooled operation with or without TEC
- 4 analog outputs
- Rolling mode bottom-to-top scanning
- 1024x768 pixels focal-plane array
- 17µm pixel pitch
- Internally computed coarse-NUC (optionally also R/W)
- Adjustable GAIN & Integration time
- Parallel/Serial communication
- Built-in (CMOS) FPA temperature diode gauge 6mV/K
- Mil-std qualification

scd SemiConductor Devices

Typical Specification

PARAMETER	PERFORMANCE
Spectral Response	8µm-12µm
Array Format	1024 x 768
Nominal Frame-Rate	60Hz
Video Output Span	2V (0.5V÷2.5V)
Power Supplies	Bolometer 6.5V; Video O/P 5.5V; Digital 1.8V
Power Dissipation	700mW (@60Hz frame rate, 25°C FPA Temp)
Temporal NETD	<45mK (F#/1, 25°C FPA Temp, 60Hz frame rate)
Thermal Time Const	12mSec
Dynamic Range	100°C (nominal gain)
Response	5mV/K to-50mV/K (selectable)
Pixel Operability	99.5%
FPA Temp. control	Thermo-Electric-Cooler
Size	52mm X 52mm X 11mm (excluding pins & vacuum tube)
Weight	32g
Operating Temp	Minus 40°C to Plus 71°C
Storage Temp	Minus 40°C to Plus 80°C
Vacuum Life Time	14 years (at 25°C Storage temp)

405265SCD/UNC/1212

SemiConductor Devices

• P.O. Box 2250, Haifa 31021 Israel • Tel: (+972)-4-9902535 9902500
• Fax: (+972)-4-9902627 • e-mail: marketing@scd.co.il • Web: www.scd.co.il

Empowered by Innovation NEC

Uncooled Infrared Imager
HX3220i

- **Small, light weight and high sensitivity**
  - *"12 µm" pixel pitch*
  - *VGA*
  - *Saving optics material and cost*
    (Lens area ratio to our 23.5 µm pitch detector: approx. 1:4)
- **Compact and light package**
  - *Easy integration*
  - *Various applications*
- **Excellent thermal image quality**
  - *EE (Edge Enhancement)*

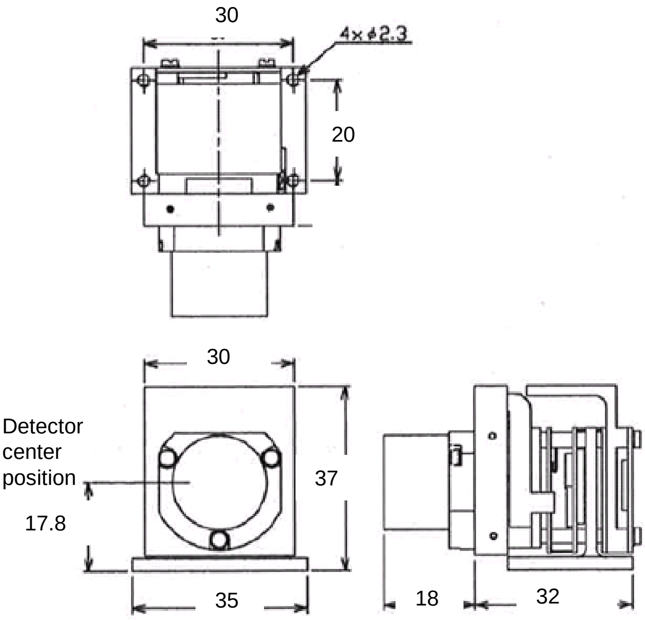
Applications

A small and low-cost IR camera allows the various applications.

Function

Image Enhancement (EE)

Enhance and optimize thermal contrast for the better situation awareness.



Accessory cable

Power input cable

● Performances and appearance described herein are subject to change without notice.

Specification and Function

Basic Specification

Pixels (H x V)	640x480
Pixel pitch	12 μm
Wavelength	8-14 μm
Flame late	NTSC : 30Hz、PAL : 25Hz
Dynamic Range	L range : -40 to 150 deg C H range : 0 to 500 deg C
NETD	75mK(F/1.0) TYP.
FOV	49°(H)×37°(V) ±5° (f=8.4mm Lens)
Focus	50cm～∞ Manual Focus
Interface	RS-232C、USB(Customers engineering use)
Video output	NTSC / PAL
Digital output	ITU-R.BT656 digital video (Cable is Not included, To be set command for output.)
Input Voltage	DC5.7～13V
Size	H 35mm x V 37mm x D 50mm (With Lens f=8.4mm)
Weight	<70g (With Lens f=8.4mm)

Functions

Contrast/Brightness	Auto / Manual
Polarity	White-hot / Black-hot
Digital Zoom	x 2, x 4
NUC*	Auto / Manual
Dynamic range selection	L / H / Auto
Image Processing	EE* Mode
Color pallet	False Color
Configuration	Yes

*NUC：Non Uniformity Correction
*EE：Edge Enhancement

Accessories

①	HX3220i Imager
②	Power cable(AC adaptor is Not included)
③	Accessory cable (RS232C interface、Video output、Function key for Menu)
④	Operation Manual

*This Uncooled infrared detector utilizes the result of the research funded by New Energy and Industrial Technology Development Organization (NEDO) of Japan.

For further information, please contact:

NEC Corporation

Electro-Optical Systems Department
Guidance and Remote Sensing Systems Department,
Radio Application Guidance and Electro-Optics Division
e-mail: window@geo.fc.nec.co.jp

WARNING NOTICE
This product (or technology or software) is controlled by export control laws and regulations of Japan. Transfer or any other disposal of this product (or technology or software) without required license from the government of countries having competent jurisdiction is prohibited.

As of March 2015

●Performances described herein are based on the NEC test condition
●Performances and appearances described herein are subject to change without notice.

Cat.DSS15CA001

ASTRONICS
MAX-VIZ
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PHONE: 503-968-3036 • FAX: 503-968-7615

REQUEST FOR COMMENTS

REGARDING AMENDMENT TO THE INTERNATIONAL TRAFFIC IN ARMS (ITAR) REGULATIONS: REVISION OF U.S. MUNITIONS LIST CATEGORY XII
RIN 1400-AD32
TO THE ATTENTION OF E-MAIL: *DDTCPublicComments@state.gov*
Max-Viz, Inc. offers the following comments below in response to RIN 1400-AD32, pertaining to changes in the controls on Category XII (fire control, range finder, optical and guidance and control equipment) of the U.S. Munitions List (USML).

RE: REVISION TO THE EXPORT ADMINISTRATION REGULATIONS (EAR): 15 CFR PARTS 734, 740, 742,744, 772 AND 774.
RIN 0694-AF75
TO THE ATTENTION OF E-MAIL: publiccomments@bis.doc.gov.
Max-Viz, Inc. offers the following comments below in response to RIN 0694-AF75 pertaining to Revision to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control under the United States Munitions List (USML).

Comments:
Max-Viz, Inc. is a small Aerospace company focused on providing Enhanced Vision Systems for civil aircraft. We have many concerns regarding the proposed changes to **ITAR 22 CFR §120-130** and **EAR 15 CFR §730-774** and their effects on our ability to remain competitive in the global market; our ability to sell, export and re-export Max-Viz, Inc. Enhanced Vision Systems known in the regulations as Thermal Imaging Cameras.

While we support the **Export Control Reform Initiative (ECRI),** clarification and a tempered approach to the commercial effects of over regulation is needed to ensure that the proposed rule changes achieve the stated goals of the **ECRI**.

Max-Viz, Inc. cameras are classified by the Department of State via CJ determination as ECCN 6A003 Camera systems. They are designed, developed and manufactured for civil use and are under the Department of Commerce control.

Regarding the proposed regulatory changes for ECCN 6A003 Cameras, and Camera systems:

- We oppose changes to 740.16(a,b) License exception APR that would restrict the use of 6A003 items to and among Country Group A:1 and cooperating countries for products, cameras and camera systems with greater than 111,000 detector elements. Some Max-Viz, Inc. products with ECCN 6A003 currently contain less than 111,000 and some contain more, such as 327,680 detector elements. All are designed for civil use. Restricting use and export would harm our company’s ability to stay competitive in the global market place.

- We oppose changes to expand 744.9 end-use and end-user requirement for all of the 6A003 items. This would require a license to export, re-export or transfer (in-country) items. If we cannot determine if our camera sent for a stocking order to an authorized integrator company (aircraft manufacturer) will be incorporated into military aircraft at the time we ship it, a license would be required for all shipments. This change would make our “authorized company” integrator license useless, and result in an increase in Export License applications. Any delays in that process delay shipments, and cause US companies such as Max-Viz, Inc. to become less competitive in the global market place for 6A003 thermal imaging cameras.

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- We oppose ECCN 6D003.c. Software that is designed for 6A003 cameras incorporating IRFPA's designated under a worldwide Regional Stability (RS) control is going backwards in time and would require a license to export everywhere including Canada. This would result in huge increase of export license applications, with unnecessary burden on a small company such as Max-Viz, Inc.

- We are very concerned and unclear about new ECCN 6D991 Software controls that are specially designed for "Development", "Production" or "Use" of 6A003 Cameras and Camera systems. We cannot determine if it affects our finished product or refers to the Software contained within our cameras. All of our cameras have internal software but do not require external software for operation. This must be clarified in order to assure we can comply with the regulation, if it is applicable. Imposing a worldwide RS control for the software that is currently EAR99 does not make sense to us and will hurt our ability to remain competitive in the global marketplace of thermal imaging cameras. Eliminating the STA exception: it is unclear why that would be ineligible, and what the rational for this is? **Because of these concerns, we oppose this as written.**

- We are very concerned and unclear about new ECCN 6D994 Software that is specially designed for "maintenance", "repair" or "overhaul" of 6A003 Cameras and Camera systems. If these controls were put into place and it refers to the software internal to our camera system then we would be unable to perform software bug fixes or software upgrades in the field without an export license. We are unable to determine if this ECCN applies to our Max-Viz, Inc. 6A003 cameras, and how it affects our finished products. This must be clarified in order to assure we can comply with the regulation, if it is applicable. Imposing a worldwide RS control for the software that is currently EAR99 does not make sense to us and will hurt our ability to remain competitive in the global marketplace of thermal imaging cameras. Eliminating the STA exception: it is unclear why that would be ineligible, and what the rational for this is? **Because of these concerns, we oppose this as written.**

- With respect to ECCN 0A919 for military commodities outside the US that incorporate our Max-Viz, Inc. 6A003 thermal imaging cameras, we disagree with increasing the scope to include Foreign military aircraft commodities.
  We sell thermal imaging cameras to aircraft manufacturers, they incorporating 6A003 cameras into helicopters, jets, fixed wing aircraft for Military or government entity use for transportation, Medical EMS use, and firefighting capabilities. An export license currently allows this. Requiring a license and restricting re-exports of 6A003 cameras installed on aircraft in this scenario, requiring a license worldwide, except Canada is an undue burden for the all parties involved and may not aid in Regional Stability as intended.
  Because of these concerns, we oppose this change.

Concerning the use of the phrase "permanent encapsulated sensor assembly" in regards to IRFPA assemblies:

- It is unclear what the term "permanent" means exactly as it is not a term normally identified with electronics. Therefore a sensor assembly could be deemed to be "not permanent enough" in its encapsulated assembly; the criteria is undefined.
- The term "encapsulated" or "casing" is not clearly defined.
- With many "encapsulated sensor assemblies" on the market, it cannot be determined with certainty if sensors are removed, whether they would become damaged or destroyed, or rendered inoperable.
- Is there a compelling reason to define the IRFPA sensors this way? We don't agree with this method.

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- Faulty sensors are returned to the manufacturer for repairs and servicing under warranty. We think this definition, and further this approach to IR sensors is misguided and unnecessary.

Because of these concerns, we oppose this new term as written.

Concerning the proposed new license requirements for the Export to Canada of our camera systems:

- We support the current export availability of 6A003 cameras to Canada.
- Increasing restrictions to require all exports obtain an export license will cause an undue burden on small companies such as Max-Viz, Inc., and will not ensure Regional Stability will benefit from this regulatory change.
- We export our ECCN 6A003 cameras to Canada for civil use and for use in Fire suppression, which may or may not be civil use contractors. We oppose the Regional Stability designation on items that today and for many years past, have not required an export license to Canada. The economic impact of this change alone would be greatly felt by a small company such as Max-Viz, Inc. It will drive Canadian companies to purchase 6A003 cameras with IRFPA's from other foreign competitors that are less regulated then the US.
- For all small companies, such as Max-Viz, Inc., the additional work added to obtain export licenses for Canada will make us less competitive in the foreign market place. Why buy American when they can go to other nations and obtain products with little to no restrictions on export to Canada? We don't believe it is the goal of ECRI to make us less competitive globally.

Summary:

We cannot emphasize enough that as a small company, Max-Viz Inc. strives to remain competitive in the Global marketplace of thermal imaging cameras. The Foreign availability for the same thermal imaging camera products is pervasive. If these restrictions are implemented as is, the regulations will severely place Max-Viz, Inc., and all other US companies, at a significant disadvantage to foreign competitors, without adding true regional stability worldwide.

The loss of revenue due to unnecessary regulatory restrictions may be substantial to Max-Viz, Inc. As all 6A003 cameras become more restricted to export, re-export and transfer under the proposed changes, will the United States truly become more secure? We think not.

We believe each of our comments will help government agencies reform the regulations more consistently and with more clarity, without increasing national security risks for the Unites States and without sacrificing Regional Stability worldwide.

Thank you for considering our comments.

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General Comment

Hereby I am providing my comments to the proposed rule RIN 1400-AD32 [Public Notice: 9110] to amend ITAR to revise Category XII of the USML, with special focus on portable night vision technology - image intensification (I2) and thermal imaging (TI).

See enclosed pdf file for reference

Many thanks in advance

Michael Connor

Attachments

Attachment1_Comment

Comment to the proposed rule RIN 1400-AD32 [Public Notice: 9110] to amend ITAR to revise Category XII of the USML, with special focus on portable night vision technology - image intensification (I^2) and thermal imaging (TI).

Date: July 3, 2015

Contents:

1.1. Introduction

This report seeks to address some of the key goals of the rulemaking, namely:

- to identify potential lack of coverage brought about by the proposed rules, in order to ensure the USML and the CCL together control all items that meet Wassenaar Arrangement commitments embodied in USML Category XII.
- to prevent inadvertent control of image intensification and thermal imaging systems on the ITAR list that are in normal commercial use and available outside of the United States in similar parameters or characteristics, therefore providing no critical military or intelligence advantage.
- to provide extensive evidence about foreign availability of such items on the worldwide market, especially Russia/ex-CIS, PR China and European Union).
- to provide specific examples of items that would be controlled by the revised USML Category XII proposed in this rule that are in normal commercial use (incl. foreign availability of such items) and should thus controlled EAR's 600 series controls

1.2. The problem of the Military classification

The general idea of the amendment is to describe more precisely the articles warranting control on the USML, in order to establish a bright line between the USML and the CCL for the control of these articles. That assumes identifying items which are commonly available on the both US and foreign commercial market as dual-use items, which do not fall under the ITAR control. This shall, in retun, open the world market for the US producers and increase the competitiveness of the US export economy. Unfortunately, the current proposed revision does not seem to address this issue as accurately as desirable.

The previous USML Category XII tried to distinguish between military and commercial night vision items by using a definition of items *specifically designed, modified or configured for military application*. Such division did no more seem to correspond with the situation on the both US domestic and foreign night vision/thermal imaging market, which has seen a major surge in availability and sheer number of types in recent years.

Currently, there are very few portable night vision / thermal imaging items which could be described as specifically designed for military use, as the widely available commercial items have caught up in terms of functionality or performance parameters. Even the types adopted for use in US or other military already are having their civilian clones, most often the same devices, albeit sold under their commercial names, with both "mil-spec" and "commercial" types sharing the same housings, optics, mounts and internals.

Chapters 3.1 and 3.2 of this report deal with the situation by correctly identifying the night vision and thermal imaging systems currently in use in the US military and providing information about types, names and availability of their commercial clones, as well as counterparts on the civilian market sporting similar functionality and performance parameters, even overcoming such obstacles as vendors and resellers on the commercial market using the popular military designation (AN/PVS) in shortened form (PVS) in order to boost sales.

Given the lack of distinction between military and commercial items described above one has to ask, why does the revised rule still list those obviously commercially available systems on the ITAR list? The reasons could be two-fold – either the performance of the military items is decisively superior to the commercial items or there is lack of availability of similar systems anywhere outside of the US, so keeping them under the ITAR control provides distinctive advantage for the US. As shown on the next pages, neither of that is true.

This stance is furthermore supported by the document "Critical Technology Assessment: Night Vision Focal Plane Arrays, Sensors and Cameras" prepared by US Department of Commerce, Bureau of Industry and Security, Office of Technology Evaluation in October 2012. According to the report findings (see p.42), with the exception of cooled thermal imagers, the number of commercial product lines for both image intensification and thermal imaging products visibly exceeds the amount of military types, although not mentioning that even the military types have their commercial clones sold under different names. That was 2012 and since then the commercial market has furthermore expanded.

The p.39 of the report provides an in-depth look into the currently available applications for night vision items which reduces the military-use-only applications to specialized items like targeting systems/pods, threat warning systems, counter-IED systems, force protection systems and missile tracking, guidance and seeker/CM systems. Despite of that, the revised rule does not seem to respect this conclusion and furthermore insists on control of image intensification and thermal imaging systems on the ITAR list.

1.3 Performance of military vs. commercial vs. ITAR-free image intensifiers

The same situation applies to Gen2 and Gen3 IIT - it is important to note that, with few exceptions noted below, there are no strictly military or commercial items. The requirements for mil-spec tubes are largely covered in the NAVSEA document which defines threshold and objective requirements for an OMNIBUS VIII contract (MX-10160GS type tube) - see Section 3.5 for reference

Threshold requirements - Resolution 64 lp/mm center, 57 lp/mm peripheral, 36 lp/mm high-light
Photocathode sensitivity 1,800 µA/lm, Radiant sensitivity 190 mA/W @ 830nm, 80 mA/W @ 880nm
Signal-to-Noise Ratio 25:1, Equivalent Background Input 3.0 E-11 lm/cm2
Luminance Gain 40,000-80,000 fL/fc @ 2E-6 fc, 10000-21000 fL/fc @ 2E-4 fc
Halo 1.0mm
Objective requirements – Resolution 72 lp/mm center, 57 lp/mm peripheral, 36 lp/mm high-light
Photocathode sensitivity 2,200 µA/lm, Radiant sensitivity 220 mA/W @ 830nm, 110 mA/W @ 880nm
Signal-to-Noise Ratio 28:1, Equivalent Background Input 2.5 E-11 lm/cm2
Luminance Gain 50,000-80,000 fL/fc @ 2E-6 fc, 12500-21000 fL/fc @ 2E-4 fc
Halo 0.8mm

Compared to that, the specs of US commercially available tubes are identical to the mil-spec one (see the corresponding ITT specsheet) featuring values of commercial F9815VG tube:

US-made ITT F9815VG requirements - Resolution 64 lp/mm center, 36 lp/mm high-light
Photocathode sensitivity 2,000 µA/lm, Radiant sensitivity 100 mA/W @ 880nm
Signal-to-Noise Ratio 25:1, Equivalent Background Input 2.5 E-11 lm/cm2 (lower value is better)
Luminance Gain 50,000-80,000 fL/fc @ 2E-6 fc, 12,500-20,000 fL/fc @ 2E-4 fc
Halo 1.0mm

These documents indicate that mil-spec tubes are identical to commercial tubes which have undergone mil-spec testing procedure and that there is no performance difference between a military and a commercial tube. Most important, however, is the comparison of the US-designed IITs with specs of the commercially available ITAR-free IITs which can be obtained without an export license. Few examples follow:

Russian-made JSC KATOD EPM101G-01-11F requirements - Resolution 68 lp/mm center
Photocathode sensitivity 2,000 µA/lm, Radiant sensitivity 190 mA/W @ 850nm
Signal-to-Noise Ratio 27:1, Equivalent Background Input 2.5 E-11 lm/cm2 (lower value is better)
Luminance Gain 35,000-80,000 lm/lm. Autogated PSU available.

Russian-made ZAO EKRAN EPM228G-11-13A requirements - Resolution 63 lp/mm center
Photocathode sensitivity 1,900 µA/lm, Radiant sensitivity 185 mA/W @ 850nm
Signal-to-Noise Ratio 50:1 (different measuring method), Equivalent Background Input 6 E-3 kd/m2
Luminance Gain 60,000 lm/lm

German-made Harder Digital HD-1520A requirements - Resolution 57-72 lp/mm center
Photocathode sensitivity 1,500-2,500 µA/lm, Radiant sensitivity 185 mA/W @ 850nm
Signal-to-Noise Ratio 19-28:1, Luminance Gain 40,000-70,000 lm/lm.

Japanese-made Hamamatsu V6833P-G requirements - Resolution 64 lp/mm center
Photocathode sensitivity 1,500 µA/lm, Radiant sensitivity 170 mA/W @ 850nm
Equivalent Background Input 1.0 E-11 lm/cm2 (lower value is better)
Autogated PSU available.

French-made DEP-Photonis XX2545 XR5 requirements - Resolution 64-72 lp/mm center, 55 lp/mm high-light, Photocathode sensitivity 700-800 µA/lm
Signal-to-Noise Ratio 25-28:1, Equivalent Background Input 1.5-2.5 E-11 lm/cm2 (lower value is better)
Luminance Gain 30,000-55,000 fL/fc @ 2E-6 fc, 10,500-18,000 fL/fc @ 2E-5 lx
Autogated PSU available.

The major European producer, Photonis, still sticks to Enhanced Gen2 technology with sensitivity values around 700-800 µA/lm but one has to keep in mind that these tubes are unfilmed, lacking the protective aluminium oxide layer which reduces the performance by roughly 20-30% depending on thickness of the protective film..

The provided values indicate that neither there are differences in specs of mil-spec vs. commercial US tubes, nor are the state-of-art ITAR-free Gen3 designs lagging behind the US products in terms of performance.

1.4 Performance of US-made vs. ITAR-free thermal imaging detectors

Similarly, a comparison between current US-made (DRS Infrared) commercial and military uncooled systems featuring sensors with array size up to 1,024x768, detector pitch of 17µm, spectral response 8-14 µm (LWIR) and video frame rate of 30 Hz shows similar ITAR-free detectors being commercially available, by French company ULIS (see specsheet of Pico1024 1,024x768 FPA as reference), with frame rate improved up to 120 Hz. Other markets (mostly in PR China) usually have the smaller 640x480 FPA array as standard, with frame rate up to 50 Hz (see specsheet of DLC640 type as reference).

1.5 Systems without equivalent on the commercial market

New development has brought up advanced technologies which are not yet available on the commercial market. These systems provide considerable advantages compared to traditional systems (18mm tubes, 6-micron core), either due to increased performance (2-micron core), lower weight (16mm tubes) or a completely new technology rendering the classic image intensification obsolete (EBAPS Electron Bombarded Active Pixel Sensor). Such items should be explicitly listed under ITAR Category XII.

Regarding thermal imaging equipment, military-use only thermal imagers are usually equipped with cooled sensor arrays providing four times the thermal sensitivity of uncooled IR viewers. These items fully represent devices *specifically designed, modified or configured for military use.*

2.1 Current definition of revision of ITAR

Revision of 3.Section 121.1 for CATEGORY XII—FIRE CONTROL, RANGE FINDER, OPTICAL AND GUIDANCE AND CONTROL EQUIPMENT:

(a) Fire control, weapons sights, aiming, and imaging systems and equipment, as follows:
…
(2) Weapon sights, weapon aiming systems or equipment, and weapon imaging systems or equipment (*e.g.,*clip-on), with or without an integrated viewer, display, or reticle, and incorporating or specially designed to incorporate any of the following:
(i) An infrared focal plane array having a peak response at a wavelength exceeding 1,000 nm;
…
(c) Infrared focal plane arrays, image intensifier tubes, night vision, electrooptic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:
(1) Image intensifier tubes (IITs) having a peak response within the wavelength range exceeding 400 nm but not exceeding 2,050 nm and incorporating either a microchannel plate described in paragraph (e)(2)(i) of this category or electron sensing device described in paragraph (e)(2)(iv) of this category, as follows, and specially designed parts and components therefor:
(i) Incorporating a multialkali photocathode having a luminous sensitivity exceeding 500 microamps per lumen (*e.g.,* GEN 2 IITs);
(ii) Incorporating a compound semiconductor photocathode having a radiant sensitivity exceeding 20 mA/W (*e.g.,* GEN 3 IITs);
(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding

30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;

…

(5) Microbolometer IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 328,000 detector elements;

…

(12) Infrared imaging camera cores (*e.g.,* modules, engines, kits), and specially designed electronics and optics therefor, having any of the following:

(i) An image intensifier tube described in paragraph (c)(1) of this category;

…

(iii) A microbolometer IRFPA described in paragraph (c)(2) of this category having greater than 328,000 detector elements, or a microbolometer IRFPA described in paragraph (c)(5) of this category;

…

(13) Binoculars, bioculars, monoculars, goggles, or head or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate any of the following, and specially designed electronics, optics, and displays therefor:

(i) An IIT controlled in this category; or

(ii) An infrared imaging camera core controlled in paragraph (c)(12)(i) through (xi) of this category;

In practical means, the current revision is aimed at further control of following items:

(a)(2)(i) - all thermal imaging weapon sights and clip-on weapons sights (spectral response 8-14 um) regardless of IRFPA size

(c)(1)(i) and (ii) – all Gen2 and Gen3 IITs with luminous sensitivity exceeding 500 µA/lm

(c)(2)(i) – all non-encapsulated IR FPA detectors, regardless of FPA size

(c)(5) – all encapsulated thermal imaging modules over 640x512 FPA

(c)(12)(i) and (iii) – all camera cores with Gen2/Gen3 IIT or IRFPA over 640x512 FPA

(c)(13)(i) and (ii) – all Gen2/Gen3 night vision systems and thermal imaging equipment over 640x512 FPA

Current revision clearly does not address the issue of trying to draw a line between night vision and thermal imaging equipment used by the military and used commercially since it keeps all items containing a Gen2/Gen3 IIT in the military category, regardless of their commercial use, commercial availability and, most important, foreign availability.

2.2 Suggestions for revision

SUGGESTION A: clearly identify items which are commercially available for non-military purposes (described in (a)(2)(i), (c)(1)(i), (c)(1)(ii), (c)(2)(i), (c)(5), (c)(12)(i), (c)(12)(iii), (c)(13)(i) and (c)(13)(ii)) and shift these items to CCL (ECCN 6A002A and 6A003A). That includes image intensifier tubes of 2nd and 3rd generation, infrared detectors up to 640x512 FPA, encapsulated infrared cores, as well as binoculars, bioculars, monoculars, goggles, weapons sights and clip-on sights incorporating these items.

Reasoning: the sections 3.1 and 3.2 of this report clearly identify these items as being of dual-use purpose, besides their military nomenclature also being available for commercial purposes (hunting, birding, security, airsoft, surveillance). At the same time, the sections 4.1, 4.2 and 4.3 of this report contain many dozens of examples to prove that night vision / thermal imaging items of similar/identical/superior performance already are widely available throughout the world and their control under ITAR not only does not prevent foreign clients from getting hold of such equipment, but even disqualifies US producers from taking their share of the worldwide market.

The section 4.1 concentrates on foreign availability of items described in (a)(2)(i) (thermal weapons sights and clip-on sights), as well as (c)(13)(i) and (c)(13)(ii) (binoculars, bioculars, monoculars, goggles, or head or helmet-mounted imaging systems or equipment). The section 4.2 provides a special focus on Chinese market which has seen a surge of various available types in the last couple of years, with many items described in (c)(5), (c)(12)(i) and (c)(12)(iii) (encapsulated thermal imaging modules and cores) available to civilians Finally, the section 4.3 concentrates on foreign availability of items described in (c)(1)(i), (c)(1)(ii) and (c)(2)(i) (Gen2 and Gen3 IITs, non-encapsulated IRFPA detectors)

SUGGESTION B: identify technologies having no equivalent on the commercial market and enhance ITAR for effective control. That includes
- image intensifiers using 2-micron pore size MCP (multi-channel plate)
- EBAPS Electron Bombarded Active Pixel Sensor technology

Reasoning: Current revision of ITAR only takes into account luminous sensitivity of the photocathode as a distinctive parameter of the IIT generation, completely disregarding pore size of the MCP. But while the Gen2 and Gen3 image intensifiers with 6-micron pore size are widely available throughout the world, the 2-micron pore size MCP intensifiers remain a critical technology not available anywhere else and thus deserving a special attention.

The same attention shall also be paid to Intevac's patented EBAPS technology based on III_V semiconductor photocathode combined with a high resolution CMOS chip anode where the electrons are amplified. This technology enables superior low-light performance without the disadvantages resulting from relatively fragile nature of the classic analogue IITs.

3.1 US domestic market - Image intensification systems

This section provides a deep insight into today's night vision market. It lists current military types, provides evidence of their commercial availability under different names and identifies numerous other commercial items providing similar/identical function and performance. Each clickable link (blue color) provides access to a commercial purchase of the specific item in question, not just general information.

3.1.1 Night vision monoculars

Military types

AN/PVS-14 – commercially sold under various names, such as ITT (Exelis) F6015, EOTech M914, L3 M914, Nightline NL914, ATN PVS-14, ATN 6015 or NE PVS-14, Insight PVS-14 and others.
AN/PVS-18 – commercially sold as L3 (EOTech) M983 [Link1, Link2, Link3] or simply PVS-18

Commercial types

Dozens of commercially available types with identical performance, such as MUM-14, Multi-Use Monocular, DVS-110, NVM-14, MOD-3, NVS-14, Puma/Coyote, Dipol D300, GT-14, NL14W, Night Spirit, NYX-14, N-14 and many others, some in biocular package like DMS-15 or dual MUM.

3.1.2 Night vision biocular goggles

Military types

AN/AVS-9 - commercially sold as Exelis F4949 [Link1, Link2, Link3], EOTech M949, NL949 or ANVIS-9
AN/AVS-6 - commercially sold as ITT F4210
AN/PVS-15 - commercially sold as M953 or NL953
AN/PVS-21 – commercially sold as LPNVG [Link1, Link2]
AN/PVS-23 - commercially sold as ITT (Exelis) F5050 [Link1 , Link2, Link3]

Commercial types

Numerous commercially available types such as NVAG-9, GBS, Eagle, G-15, Sentinel, BNVD-G, BNVD-SG, PS-15, P15, NAV-6 and others.

3.1.3 Night vision goggles

Military types

AN/PVS-7 – commercially sold as ITT F5001, L3 M963, NL963, SNVG-7, ATN PVS7 or simply PVS-7B

Commercial types

Numerous commercially available types like NYX-7, ATN NVG7, NVS7 and others, incl. almost identical PVS-7 clones made by different suppliers, such as ATN NVB series.

3.1.4 Night vision weapons sights

Military types
AN/PVS -4 - commercially sold as NAIT PVS-4, TNV/PVS-4 or other names
AN/PVS-10 – commercially sold as SNS2142 or NightLine SNS, currently discontinued
AN/PVS-12 - commercially sold as WS2154 Aquila, Nightline NL2150, M644, Night Hawk, Talon, NH-4 or Raptor
AN/PVS-17 – commercially sold as M955 or M957

Commercial types
dozens of commercially available types of various origin (US, Russia, Belarus) with either US or European tubes, such as Litton M845, NVD-Avenger, Dedal (Russia) series D740 Argus, D750 Marauder, D760 Gladius, D790 Magnus, NVD-740, NVD-750, NVD-760, NVD-790, NVWS-6, Armasight series (Vulcan, Nemesis)

3.1.5 Night vision clip-on sights (front attachments sights)

Military types
AN/PVS-22 - commercially sold as FLIR T105, UNS, NVD-BNS, BNS or PVS-22
AN/PVS-24 - commercially sold as M2124
AN/PVS-24A – commercially sold as M2124-LRX or CNVD-LR. Also available in the EU [Link]
AN/PVS-26 – commercially sold as KAC UNS-LR
AN/PVS-27 - commercially sold as Magnum UNS, MUNS, NVD-BNS-LR or FLIR S135
Commercial types
dozens of commercial types, such as SNVG-CNVD, T90 TaNS, MilSight TaNS, CO-LR, CO-MR, CO-X, CO-Mini, ATN PS22, ATN PS28, SPA SXR, Night Probe, UNS-A2, UNS-SR and many others.

3.1.6 Dual sensor fusion systems

Military types
Dual sensor fusion systems with thermal video overlay first appeared in 2002 and today are already available to civilians. The package is either embedded in a single device or the sensor fused system consists of a night vision device combined with a clip-on thermal system.

AN/PSQ-20A - commercially sold as DSNVG [Link1, Link2, Link3]
AN/PSQ-20 SENVG - commercially sold as SENVG or Exelis Night Enforcer - Fusion
AN/PAS-29 – commercially sold as Optics1 COTI [Link1, Link2, Link3]

Commercial types
FLIR M32-C, ATN FIITS-14

3.1.7. Image intensifiers

Currently produced 18mm image intensifiers in all available formats and their civilian clones/ counterparts are listed below. Some vendors on the US market are also able to repot and repackage image intensifiers under their own brand (AEOptics) or they relabel the existing tubes with their own brand name (Nivisys), making tracing their origin by a client or even classification as military or commercial practically impossible.

MX-11769 format (36mm, inverted output, manual gain) – commercially available as ITT (Exelis) F9815 [Link1, Link2] or L3 (EOTech) M814. Used in AN/PVS-14, AN/PVS-22, AN/PVS-27 and their commercial clones, BNVD-G, etc.

MX-10130 format (43mm, PVS-7 type, straight output) – commercially available as ITT (Exelis) F9810 [Link2] or L3 (EOTech) M891. Used in AN/PVS-7 and Litton M993-995 Ranger scopes.

MX-10160 format (36mm, slim ANVIS, inverted output) – commercially available as ITT (Exelis) F9800 [Link2] or L3 (EOTech) M890 [Link1, Link2]. Used in AN/PVS-18, AN/PVS-12, AN/AVS-9, AN/PVS-15, AN/PVS-23, Insight MUM and numerous other types of monoculars, weapon sights, clip-on weapon sights and biocular goggles.

3.1.8 Image intensification systems without equivalent on the commercial market

Systems using 2-micron pore size MCP based intensifiers – exhibiting an increase in the MTF over a standard, commercially sold intensifiers with 6-micron pore size [Link1, Link2]

Systems using 16mm image intensifiers (ordered 2008) – already available on the market, yet still with restrictions for military, LE and other qualified personnel
AN/PSQ-36 - sold as FGS Fused Goggle System [Link1,Link2]
AN/PSQ-20B - sold as EOTech ENVG,
AN/PVS-31 - sold as EOTech BNVD [Link1, Link2]
i-Aware TM-NVG – designated F6045
Panoramic Night Vision Goggles - sold as GPNVG [Link1, Link2]

Systems using EBAPS Electron Bombarded Active Pixel Sensor – INTEVAC patented ultra-low-light technology (ISIE11 sensor), used in DNVG digital NV goggles, M-TADS/PNVS of AH-64E Apache helicopter or Gen3 HDMS (helmet mounted display) system of the F-35 strike fighter.

3.2 US domestic market – Thermal imaging systems

This section provides a deep insight into today's thermal imaging market. It lists current military types, provides evidence of their commercial availability under different names and identifies numerous other commercial items providing similar/identical function and performance. Each clickable link (blue color) provides access to a commercial purchase of the specific item in question, not just general information.

3.2.1 Thermal imaging monoculars

Thermal monocular have never found widespread use in the military. The most notable item is the Insight MTM (Multi-use Thermal Monocular), later adopted for military use as AN/PAS-23. The type is also offered on the commercial market as MTM, with the embedded IR laser pointer (which violates current US laws) replaced by a laser operating in the visible spectrum.

Military types
AN/PAS-23 - commercially sold as HTMI or Insight MTM (IR laser), also the commercially available Insight MTM with red laser

Commercial types
Numerous commercially available types, such as HTMI-2, Recon M24, Recon M18, UTMX, ATN Odin, OTS-X, BAe SkeetIR and UTM (slso available in Russia)

3.2.2 Thermal imaging goggles

Military types
No currently known thermal goggles with military designation.

Commercial types
Few commercially available types such as T7, GSCI TIG-7, Vulkan, TG-7 or Alpha TIG-7

3.2.3 Thermal imaging binoculars

Military types
AN/PAS-28 – Canadian-made ELCAN PhantomIR/XR, offered under its original brand name by ATN, NiteVis or OpticsPlanet, since then discontinued, mostly due to high price and other, lower priced alternatives available. Its Canadian origin enables availability outside of the US (Indonesia, Singapore, etc.)

Commercial types
Several commercially available items, such as BAe UTB, Armasight Helios, Recon BN10, BTS or FLIR BHS.

3.2.4 Thermal imaging weapons sights

Military types
AN/PAS-13C(V)1 – commercially sold as ATS3200 LTWS [Link1, Link2]
AN/PAS-13C(V)2 – commercially sold as ATS5000 MTWS [Link1, Link2]
AN/PAS-13C(V)3 – commercially sold as ATS6000 HTWS [Link1, Link2]
AN/PAS-13D(V)2 – commercially sold as NVS UT3500 MTWS
AN/PAS-13D(V)3 – commercially sold as NVS CS6000 HTWS
AN/PAS-13G(V)1 – commercially sold as L3 LTWS [Link2]

At the same time, the commercial market has been virtually flooded by numerous civilian types, with performance identical to the types used in the military, for example GSCI TWS-3000 series, FLIR RS series, FLIR R series, ATN ThOR series or TWS-13 series , SPi X25, X26, X35, T14X, PAS-15, NO Panther, SpecterIR, Apex, TAWS, Armasight series (Predator, Zeus), Bulgarian Optix series resold by SMVG (MTMS384, MTWS384, IR Hunter) or the older BST-sensor equipped Raytheon W1000

3.2.5 Thermal imaging clip-on weapons sights (front attachment sights)

Military types
AN/PAS-27 – commercially sold as IWNS-T, CNVD-T or X27.

Commercial types
A wide array of available types, such as CNVD-T2, CNVD-T3, X39, T60 ATWS, T50, T70, X24, X28, UTAC, Armasight Apollo, Phoenix, Panther, BAe UTCX, ATN Tico, TC35, TC50 and others.

3.2.6 Portable thermal imaging systems without equivalent on the commercial market

Military-use only handheld, tripod-mounted, weapon-mounted or vehicle-mounted thermal imagers, usually combined with specialized functions (switch from NFOV to WFOV, magnetic fluxgate compass, laser rangefinder, embedded GPS, laser pointer/laser designator, integrated targeting system, additional day channel). These are usually equipped with cooled sensor arrays providing four times the thermal sensitivity of uncooled IR viewers. These items fully represent devices *specifically designed, modified or configured for military us.*

AN/PAS-13B – Raytheon TWS series existing in the typical (V)1 LTWS, (V)2 MTWS and (V)3 HTWS scale. Already obsolete, with some items now having found their way to commercial market
AN/PAS-18 – Stinger Weapon Sight, specifically designed for use with FIM-92 Stinger SAM launcher
AN/PAS-21 – US designed FLIR SeeSpot III, with a 1.06um laser target designator and cooled sensor
AN/PAS-22 – Israeli made Elbit LRTI (Long Range Thermal Imager), with cooled InSb sensor
AN/PAS-24/24A – FLIR MilCam Recon III
AN/PAS-25 – Israeli-made Elbit TLSI (Thermal Laser Spot Imager) with cooled InSb sensor
AN/PAS-26 – FLIR MilCam Recon III MR
Infrared engines utilizing Cryogenic coolers
4-MP Infrared Sensor Engine – 2Kx2K cooled imaging engine
16-MP Infrared Sensor Engine – 4Kx4K cooled imaging engine

4.1 Worldwide market - major foreign manufacturers of commercially available image intensification and thermal imaging equipment

This section provides a deep insight into today's worldwide market. Not only it lists numerous ITAR-free types, but it also provides evidence of their free commercial availability. It is not aimed at resellers providing such items to military, law enforcement or government bodies under export licensing rather than commercial resellers whose items are freely available to anyone. It has to be noted that US-produced designs are almost completely absent on the worldwide market, with ITAR regulations being the major obstacle. The wide availability, as well as the sheer number of various producers and vendors of ITAR-free types shall provide evidence to form a decision regd. usefulness of further control of these items at the cost of US competitiveness on the worldwide market. Each clickable link in this section provides access to dozens of types from the specific manufacturer, which are meeting criteria for the USML list. The reseller information then provides clickable links for access to the commercial purchase of the specific item in question outside of the United States.

InfraTech (Moscow, Russia)
PORTFOLIO: maker and direct reseller of commercial night vision (Gen2+, Gen3, Gen3+) and thermal imaging equipment with up to 640x480 FPA (NV weapon sights IT-104 up to IT-406 series, NV clip-on sights IT-320 series, NV monoculars IT-331 series, IR lasers L-01 up to L-05 series, thermal weapon sights IT-1TWS series, thermal clip-on sights IT-1TCWS series)

RESELLERS: InfraTech products are resold by a number of hunting shops across Russia (30-06, Allammo, NVOptic, Okhotnik, Hunt.ru, Pricelsya, Omega-A, Optics4U, and many others) or Ukraine (igun, KEEP, ZOptics, Hunterstore).

Inwetech (Moscow, Russia)
PORTFOLIO: producer and supplier of thermal imaging equipment with cores up to 640x512 FPA**, incl.** thermal weapon sights (LF series), thermal monoculars (LF series), thermal imaging modules (LW, MW, SWIR) and thermal clip-on sights (Nano)

RESELLERS: Russia (Allammo, Optik-shop, KAEC, Salon-Arms), Ukraine (Hunterstore), Kazakhstan (SATU) and others
RESELLERS (EU): Germany (Gun-Tec)

Thermoray (Moscow, Russia)
PORTFOLIO: Designer and producer of thermal weapon sights and thermal monoculars - (TRS-640 series, TRS'M-640 series)

RESELLERS: Russia (30-06, Teplovizor)

Dedal (Moscow, Russia)

PORTFOLIO: Gen2+/Gen3 night vision equipment, thermal imaging deviced with cores up to 640x480 FPA, incl. NV goggles/monoculars (DVS/D370 series), NV weapon sights (D-1xx/4xx series), NV clip-on sights (D-5xx series), thermal vision weapon sights (T- series), clip-on sights (TA- series) and thermal goggles (TG-1)

RESELLERS: Australia (NV Australia), Ukraine (Hunterstore, CobraShop, Vustrel), Russia (Beenokli, Tut, OpticsTrade), China (Ronger) and many others.
RESELLERS (EU): Netherlands (nightvision.nl), Germany (Alpinhunting, Gun-Tec, Alpha Photonics, MOPS), Croatia (Biros), Slovakia (Armory), Netherlands (JVS-Outdoor, Gero Trading, nightvision.nl, Lahoux), Spain (Guntec), Hungary (Ejjellato, Dedal Hungary) and many others

LZOS (Lytkarino, Russia)

PORTFOLIO: designer, manufacturer and supplier of military and commercial night vision devices (ONV goggles, MNV monoculars), thermal weapon sights (IR160 series), thermal imaging scopes (IR300, IR500 series, night vision weapon sights (SM-3 series) and aviators goggles (ONV-1 series). Thermal imaging weapon sights have the cores up to 640x480 FPA and are resold by a commercial entity Fortuna ONE (Moscow, Russia).

RESELLERS: Russia (FortunaOne brand, Tut, Allammo, Teplovizor), Ukraine (Hunterstore), USA (ArmyRus)
RESELLERS (EU): Guide brand: Slovakia (Armory), Hungary (Vadasztavcso), United Kingdom (Scott Country, ThomasJacks)

NPZ Optics (Novosibirsk, Russia)

PORTFOLIO: NPZ products are widely used by Russian military but they are also offered for sale under civilian designations (e.g. PN-6K). NPZ offers a wide array of Gen2+/Gen3 night vision weapon sights (PN- series), night vision goggles and monoculars (PN-14, PN-9, PN-11, PN-21), as well as thermal imaging products (PT series sights and monoculars)

RESELLERS: Russia (InfraOpt, OpticsTrade)

JSC KATOD (Novosibirsk and Moscow, Russia)

PORTFOLIO: night vision goggles (ONV series), night vision monoculars (MNV-K series), night vision weapons sights (NMP series)

RESELLERS: Canada (Newcon), Russia (Opticstrade, TUT, Optics4U)
RESELLERS (EU): Finland (Teleskooppi)

Spektr-AT (Moscow, Russia)
PORTFOLIO: thermal weapon sights (Granit-E and Granit-12 series), thermal modules, thermal goggles (Cyclop-2 type)

RESELLERS: Russia (Teplovizor, SignalTest)

BelOMO / LEMT (Minsk, Belarus)
PORTFOLIO: wide spectrum of night vision devices (NV/G-10 G-14 and G-16 goggles, NV/M-19 monoculars, NV/S-17 and S-18 and S-21 weapons sights, TV/S-02 thermal imaging sight, TV/M-19-25-35 thermal monocular)

RESELLERS: Ukraine (Hunter Store, Nadavi), Russia (TIU, Extreme Hunter),

Pulsar (Lida, Belarus)
PORTFOLIO: maker and direct reseller of commercial night vision (Gen2+, Gen3) and thermal imaging equipment with up to 388x284 FPA, featuring night vision monoculars, night vision binoculars/ goggles, night vision weapon sights, thermal scopes, thermal weapon sights)

RESELLERS: Russia (Medved, Tut, Tulon24, WHT, 30-06, Sturman, Beenokli), Ukraine (ZOptics, Strelok, Vustrel, CobraShop), Belarus (Megaflay), Australia (NV Australia) and others
RESELLERS (EU): United Kingdom (Night Vision Store, Scott Country), Netherlands (Gero Trading, Optics World), Germany (MOPS) and elsewhere

ElectroOptic (Minsk, Belarus)
PORTFOLIO: manufacturer and supplier of thermal imaging weapon scopes (TS series, T series), thermal monoculars (TM-2, SND-1 binocular) and multi-spectral systems (SND-2), night vision scopes (SM-3 series) and day-night weapon scopes (SM-3S2DN).

RESELLERS: USA (ArmyRus), Belarus (Okhota)
RESELLERS (EU): United Kingdom (Dauntsey Guns, Night Vision Store), Czech Republic (Night Hunter), Slovakia (Hubert)

Dipol (Vitebsk, Belarus)
PORTFOLIO: maker of commercial night vision (Gen2+, Gen3) and thermal imaging equipment, featuring thermal goggles (TG-1), thermal weapon sights (D71T), NV weapon sights (D-series), NV monoculars (D127, D128 or AM8), NV bioculars (D221), and NV goggles (D206, D209).

RESELLERS: Australia (NV Australia), Ukraine (CobraShop), Russia (Allammo, Extreme Hunter), etc.
RESELLERS (EU): Slovakia (Szolgai, TT-hunt, Hunters), Hungary (tavcso), Netherlands (Gero Trading), United Kingdom (CobraOptics), Germany (MOPS) and elsewhere.

New Effect (Sabinov, Slovak Republic)
PORTFOLIO: designer, manufacturer and reseller of commercial night vision and thermal imaging equipment, incl. EAGLE-TSV series thermal monoculars, thermal goggles and thermal weapon sights, as well as EAGLE M3 series night vision monoculars

RESELLERS (EU): Czech Republic (Nocni videni), direct ordering across the whole European Union

Thermal Vision Technologies (Kiev, Ukraine)
PORTFOLIO: thermal imaging equipment with cores up to 640x512 FPA**,** thermal monoculars (TMA series), thermal goggles (TGA, TGX series) and thermal weapon sights (TSA series)

RESELLERS: Ukraine (Hunterstore, CobraShop, Donbas Spetspribor), Russia (OptiVision, Krot), USA (under NightOptics brand, BH, MilitaryTechs, NV Universe), Canada (under Newcon brand), Indonesia (Ngeker) and others
RESELLERS (EU): Hungary (Vadasztavcso), Czech Republic (TVT-Europe), Netherlands (Optics World, Lahoux) and others.

GSCI Night Vision (Richmond Hill, Canada)
PORTFOLIO: designer, manufacturer and direct reseller of commercial night vision and thermal imaging systems (up to 640x512 FPA), featuring Thermal imaging systems (TIM-14, TIG7, TIB-5000), Thermal Weapon Sights (CTS-200, TWS-3000 series) Ultra Long Range TI systems (TLR-7000), night vision systems (PVS-14, PBS-14, GS-14, PVS-7, GS-7, PVS-31), night vision weapon sights (PBS-14, CNVD-22, GS-26) and enhanced sensor fusion systems (ClipIR, ENVG-7, ENVM-14, ENVB-31).

RESELLERS: GSCI products are resold by importers in Canada (Tactical Imports, Twenty20Insight, GSCI Direct), USA (NightVisionHome, NVUniverse, TNVC), New Zealand (Owl Optics), Australia (NV Australia), Russia (Prizel, Mil-Dot, Allammo), Ukraine (Vustrel), Kazakhstan (PnV) and others
RESELLERS (EU): United Kingdom (Night Vision Store), Netherlands (MSS, Gero Trading, nightvision.nl), Italy (LiviOptik), Hungary (Vadasztavcso), Spain (ATNVES), Germany (Alpinhunting, Alpha Photonics, MOPS), Croatia (Biros) and elsewhere.

Newcon Optik (Toronto, Canada)
PORTFOLIO: designer, producer and reseller of commercial night vision and thermal imaging equipment, incl. Gen2+/Gen3 night vision systems, such as NV monoculars (NVS14 series), NV goggles (NVS7 series), NV weapon sights (DN series), aviators goggles, and thermal imagers (monoculars, binoculars and weapon sights. Some items are Russian made. Newcon also offers Russian-made Gen2+/Gen3 image intensifiers (by JSC Katod)

RESELLERS: Canada (Tactical Imports), USA (Outdoorsbay), Russia (Shopotam), Taiwan (Jiun-An)
RESELLERS (EU): Italy (LiviOptik), Sweden (Handla Digitalt), United Kingdom (Dragon Supplies) and others.

AT N Night Vision Corp. (San Francisco, USA) / OOO COT (Moscow, Russia)
PORTFOLIO: designer, producer and reseller of commercial night vision and thermal imaging equipment, incl. Gen2+/Gen3 night vision systems, such as NV monoculars (NVM14, Night Spirit, PVS-14/ATN 6015), NV goggles (NVG7, PVS-7), NV weapon sights (NightArrow, Ares), NV clip-on sights (PS28) and thermal imagers (Odin and OTS-X series monoculars, Tico clip-on sights and ThOR series weapon sights). Many items from the ATN portfolio are actually Russian types designed and manufactured by OOO COT (Moscow, Russia).

RESELLERS: New Zealand (Owl Optics), Ukraine (CobraShop, Hunter Store, Profoptica), Russia (Prizel, Ohotnik, Kuban, WHT, Beenokli, Z-ohotnik), USA (Cabelas), Indonesia (AsiaScopes), Australia (Night Hunter) and many others
RESELLERS (EU): Spain (ATNVES), United Kingdom (Scott Country), Slovakia (IBO), Czech Republic (Nocni videni, Night Pearl), Slovenia (Optics Trade), Netherlands (Optics World), Italy (Visori), and many others.

Armasight (San Francisco, USA)
PORTFOLIO: Designer and producer of night vision goggles (Nyx7, PVS-7 series), biocular goggles (N15 series), monoculars (Avenger, Sirius, NYX-14, PVS-14 series), dedicated weapons sights (Spear, Nemesis, Vulcan series), night vision clip-on sights (Co-Mini, CO-MR, CO-LR, CO-X series), thermal imaging monoculars (Prometheus, Q14 series), binoculars (Helios series), weapons sights (Predator, Zeus series) and clip-on weapons sights (Apollo series)

RESELLERS: Ukraine (CobraShop, Hotline), Russia (Prizel, Tut, Shopotam), Kazakhstan (PnV), USA (Opticsplanet, Armasight Store, Cabelas), Indonesia (AsiaScopes, Prima iceindo), South Africa (Armasight South Africa), Australia (Owen Guns, Survival Supplies), PR China (Shanghai Anjun) and many others.
RESELLERS (EU): Spain (ATNVES), Slovakia (Armory, Puskohlady, RAJ), United Kingdom (NightVisionGear), Sweden (Handla Digitalt), Czech Republic (e-lovec, Night Pearl), Spain (Guntec), Germany (Alpha Photonics), Netherlands (JVS-Outdoor, Optics World), Italy (LiviOptik) and many others.

Optix (Panagyurishte, Bulgaria)
PORTFOLIO: Gen2+/Gen3 night vision equipment and thermal imaging equipment with cores up to 388x284 FPA, incl. night vision front attachment sights (FireFly-3, FireFly-4, Marksman), NV binoculars (Forester), NV monoculars (Boarhunter, Hillwalker dual), thermal weapon sights (IdentifieR series), thermal monoculars (RecognizIR) and clip-on sights (ZIR). These devices are civilian closes of Optix's DIANA military lineage.

RESELLERS: USA (NiteHog, SNVG), Russia (branded Skanda, Tut) etc.
RESELLERS (EU): Hungary (Vadasztavcso), Netherlands (MSS), Bulgaria (Kintex, Classic-Safaris), Slovakia (M-Hunt), Germany (Geiger), United Kingdom (Rovicom) and others.

Liemke Defence (Bielefeld, Germany)
PORTFOLIO: own civilian lineage of thermal weapons sights (MR series), binoculars (BN series), and monoculars (M series)

RESELLERS (EU): Germany (LK-Shop), direct ordering across the whole European Union

VHF Defence (Zirndorf, Germany)
PORTFOLIO: thermal imaging viewers and weapons sights (Raubtier series) up to 1024x768 FPA

RESELLERS: Norway (Jevnaker), **RESELLERS (EU):** Finland (FinAccuracy), Germany (IEA)

IEA Night Tronic (Germany)
PORTFOLIO: night vision monoculars (NT940, NT941 and NT920 (PVS-14) series), night vision goggles (NT910 (PVS-7)), night vision biocular goggles (NT931), night vision weapons sights (NT740/760 (PVS-12), Zeiss Orion series), night vision clip-on sights (PVS-24 series), thermal clip-on systems (L3 COTI), thermal clip-on weapons sights (CNVD-T series), thermal weapons sights (LTWS)

RESELLERS: Switzerland (TacStore)
RESELLERS (EU): Finland (FinAccuracy), Germany (Jagd-Zentrum, Askari, MGC, Frankonia-Jagd, MOPS) and others

Cassidian Zeiss (Hensoldt, Germany)
PORTFOLIO: night vision clip-on sights (NSV series) and thermal clip-on sights (IRV series)
RESELLERS (EU): Netherlands (Optics World), Finland (FinAccuracy), Italy (LiviOptik), France (PGM Precision), Sweden (Handla Digitalt)

Thermoteknix (Waterbeach, United Kingdom)
PORTFOLIO: thermal imaging monoculars (TiCAM series), long range thermal imager (TiCAM 750LR), thermal imaging clip-on systems (ClipIR), LWIR thermal imaging cores (MIRICLE, MicroCAM series, MicroCAM HD, MicroCAM irGO) with resolution up to 1024x768 FPA (17µm pitch).

RESELLERS: Singapore, Malaysia, Indonesia, Vietnam (Adlertech), Mexico (JP Innovatec)
RESELLERS (EU): United Kingdom (ThomasJacks), Poland (Raytech), Netherlands (Lahoux), Germany (Geiger) and others.

Pyser-SGI (Edenbridge, United Kingdom)
PORTFOLIO: NV monoculars (PNP series), NV goggles (PNG series), weapons sights (PNP-MT series), thermal imaging products (weapons sights, clip-on sights and fusion systems)

RESELLERS: Singapore (Pyser-SGI Asia), **RESELLERS (EU):** Germany (LK-Shop)

4.2. Mainland China market - major manufacturers and suppliers of commercially available image intensification and thermal imaging equipment

Chinese products are traditionally resold on online marketplaces like Made-In-China or Alibaba. The system is different from the established system of vendors in the western world. Night vision and thermal imaging products of Chinese origin can be obtained directly from the respective manufacturers via marketplaces like Made-in-China, Shenzhen, Alibaba, Manufacturer.com, or Asian Products. Few largest suppliers are presented below, incl. their portfolio of products and clickable links proving their availability for a commercial purchase, even in small numbers.

Yiwu TianYing Optical Instrument
PORTFOLIO: thermal weapon sights (TWS- series), thermal imaging scopes (XD- series), thermal binoculars (Identifier), thermal imaging cores (up to 640x512 FPA), night vision scopes (Giant series) and night vision weapon sights (Sniper series)

Kunming ProNV Technology
PORTFOLIO: Gen2+/Gen3 night vision goggles (OHB-Y type), NV monoculars (MHB type), Gen2+/Gen3 NV weapons sights (CR series), thermal weapon sights (ZK series)

Shenzhen Ronger Optics and Electronics
PORTFOLIO: Gen2+/Gen3 NV monoculars (MHB series), NV goggles (OHB series), NV weapons sights (D-series, Centurion series), thermal weapons sights (by Yiwu)

Xian MH Electronics
PORTFOLIO: uncooled infrared FPA detectors up to 384x288 FPA, thermal imaging cameras

Zhejiang Zhaosheng Technologies
PORTFOLIO: thermal imaging binoculars/scopes (T300 series), thermal imaging modules up to 640x480 FPA (17µm pitch)

JIR Hubei Jiuzhiyang Infrared System
PORTFOLIO: thermal imaging modules up to 640x480 FPA, thermal imaging scopes/binoculars (JIR brand)

Zheijang Dali Technology
PORTFOLIO: uncooled infrared FPA detectors up to 640x480 FPA, encapsulated infrared modules, handheld thermal imaging devices (S230-S730 series)

Zheijang ULIRVision Technology
PORTFOLIO: thermal imaging modules up to 640x480 FPA, thermal imaging monoculars and weapons sights (Venus and Eagle series)

Wuhan Guide Infrared
PORTFOLIO: thermal imaging detectors, (LWIR, uncooled, cooled) up to 640x480 FPA, handheld thermal imagers (IR series). Resold in UK (Night Vision Store) and Germany (LK-Shop, Geiger)

Zhejian Zybron Industry
PORTFOLIO: handheld thermal binoculars (TS and TF series), thermal imaging cores up to 640x480 FPA (17µm pitch)

Shenzhen Daking Optoelectronics
PORTFOLIO: Gen2+/Gen3 NV goggles, NV monoculars,

Golden Eagle Outdoor and Optics
PORTFOLIO: thermal imaging monoculars, Gen2+/Gen3 night vision equipment (monoculars, goggles, weapons sights)

JAXY Optical instrument
PORTFOLIO: Russian (PN-14) and Chinese (WYJ type) Gen2+/Gen3 night vision goggles, uncooled thermal imagers (SNS-V type)

Yunnan New Era Trade
PORTFOLIO: Chinese military night vision goggles (NV01 type) and night vision weapons sights (NV04/05/06 type)

Shenzhen Xinxing Southern Industrial Development
PORTFOLIO: Gen2+/Gen3 night vision goggles (AT series)

Dynamic Security Company
PORTFOLIO: Gen3 night vision items and image intensifiers

4.3 Worldwide market - major foreign manufacturers of commercially available image intensifiers and thermal imaging detectors

The deep insight into today's worldwide market ends with a list of major worldwide manufacturers and providers of ITAR-free image intensifier tubes and non-encapsulated IRFPA sensors which are used in the night vision and thermal imaging equipment across the whole world outside of the United States. Pleae, note that the once so precious Gen3 GaAs technology has finally widespread to the world, especially thanks to two major Russian producers and that ITAR-free IITs with luminous sensitivity over 1800 µA/lm are slowly becoming a standard rather than an exception. Again, the US-produced designs are practically completely absent on the worldwide market, with ITAR regulations being the major obstacle.

Harder Digital (Woltersdorf, Germany / Nis, Serbia)
PORTFOLIO: Gen2+ and Gen3 GaAs image intensifiers with resolution up to 72 lp/mm, sensitivity up to 2500 µA/lm and SNR up to 28:1. Uses Russian cores and MCPs with German developed PSU (power supply unit). Available directly from Serbia (Sova night vision) or Germany (Harder Digital).

Photonis Technologies (Brive, France / Roden, Netherlands)
PORTFOLIO: 18mm and 16mm image intensifiers (XR5, XD-4), integrated image intensification cameras, autogated power supply, unfilmed, INTENS technology with extended bandwidth, resolution up to 72 lp/mm and SNR up to 28:1. Photonis has many resellers in Europe, namely in Germany (Alpha Photonics, IEA, Direct Industry), Netherlands (Lahoux Optics), Italy (Visori) or United Kingdom (MRL), but also in USA (Photonis USA) or Russia (Lahoux Russia).

JSC KATOD (Novosibirsk and Moscow, Russia)
PORTFOLIO: a wide array of 18mm Gen2+ and Gen3 GaAs image intensifiers, with resolution up to 68 lp/mm, sensitivity up to 2000 µA/lm and SNR up to 27:1**,** Including many 36mm slim ANVIS types with inverted output and 43mm non-inverted types, fully compatible with PVS-7 type pseudo-binocular devices. These tubes can be obtained directly from Russia, and are also resold in Canada (Newcon Optik) or Spain (Guntec).

EKRAN-FEP (Novosibirsk, Russia)
PORTFOLIO: 18mm Gen2+ and Gen3 GaAs image intensifiers, with resolution up to 68 lp/mm, sensitivity up to 1900 µA/lm and SNR up to 27:1. The portfolio includes many 36mm slim ANVIS types or 43mm PVS-7 types. Besides Russia, these tubes are commercially available in Europe (Alpha Photonics)

Hamamatsu Photonics (Hamamatsu-City, Shizuoka, Japan)
PORTFOLIO: Gen3 GaAs image intensifiers, with resolution up to 65 lp/mm, and SNR up to 25:1. Primarily a producer of laboratory intensifiers, the portfolio includes a 36mm slim ANVIS compatible intensifier of V6833P type with inverted output and 43mm straight tube of V7090P type for night vision goggles. In Europe available at Geiger Optronix.

Hioptic, Chinese Military & Professional Optics Corp (Nanjing, JiangSu, PR China)
PORTFOLIO: 18mm enhanced Gen2 image intensifiers, with resolution up to 68 lp/mm and SNR up to 20:1. The high performance types are most likely licensed by Photonis-DEP.

North Night Vision Technology Co. (Kunming, Yunnan, PR China)
PORTFOLIO: 18mm Super Gen2 and Gen3 GaAs image intensifiers, 16mm image intensifiers, with autogated power supply, with resolution up to 72 lp/mm, sensitivity up to 2500 µA/lm and SNR up to 28:1. Most likely in close cooperation with Russian JSC Katod.

ProxiVision GmbH (Bensheim, Germany)
PORTFOLIO: Gen2 based 18mm, 25mm and 40mm image intensifiers

ULIS (Veurey-Voroize, France) / Sofradir Group (Palaiseau, France)
PORTFOLIO: uncooled silicon IR detectors with resolution up to 1024x768 FPA (17µm pitch) (Pico384, Pico640, Pico1024, Micro80 series)

Sofradir-EC (representative in the United States, Fairfield, NJ, USA)
PORTFOLIO: uncooled silicon IR detectors with resolution up to 1024x768 FPA (17µm pitch), cooled detectors (MCT Mercury Cadmium Telluride, InSb Indium Antimonide, InGaAs Indium Gallium Arsenide and QWIP Quantum Well detectors with resolution up to 1024x1024 FPA)

Xenics NV (Leuven, Belgium)
PORTFOLIO: advanced VOx infrared imagers, cameras and modules with cores up to 640x512 FPA (Gobi, Bobcat, Xeva, Cheetah, Cougar, Lynx and other series)

INO (Quebec, Canada)
PORTFOLIO: uncooled infrared FPA detectors up to 384x288 FPA, IRXCAM infrared modules up to 1024x768 pixels, HRXCAM HD infrared modules up to 2048x1536 pixels

NIT (Madrid, Spain)
PORTFOLIO: uncooled MWIR microdetectors (Tachyon, Matrix, Luxell, Lepton series)

Xian MH Electronics (Xian, PR China)
PORTFOLIO: uncooled infrared FPA detectors up to 384x288 FPA

Zheijang Dali Technology (Zhejiang, PR China)
PORTFOLIO: uncooled infrared FPA detectors up to 640x480 FPA (17µm pitch)

Wuhan Guide Infrared (Wuhan, PR China)
PORTFOLIO: thermal imaging detectors (LWIR, uncooled, cooled) up to 640x480 FPA (17µm pitch)

5.1 Conclusion

This report has set a demanding target from the outset – to act as a solid source of specific and verifyable information for the lawmakers regarding the commercial availability of the items currently controlled on the ITAR list, Category XII. The author of this report thinks that the ECR initiative of the President of the United States provides an excellent opportunity to abandon the Cold War era export control laws in the areas where they no longer reflect the situation on the worldwide commercial market. Unfortunately, the currently proposed revision of the Category XII does not seem to reflect the situation described, quite on the contrary, it inadvertently continues to control image intensification and thermal imaging systems which a civilian can buy for normal commercial use in almost any country on this planet, often in similar parameters or characteristics to the items which ITAR continues to control. A revision as currently proposed is a missed opportunity to boost the US exports by enabling the US producers to effectively compete on the worldwide market. The suggestions described in the Section 2.2 of this report show a way how to make this opportunity to an advantage for the future.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Maria T. Zuber
Vice President for Research
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July 6, 2015

Office of Defense Trade Controls Policy
U.S. Department of State
By email to DDTCpubliccomments@state.gov, subject "ITAR Amendment—Category XII"
RE: RIN 1400-AD32

MIT appreciates the opportunity to comment in response to the Bureau of Industry and Security (BIS) RIN 1400-AD32, *Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions list Category XII*. Our comments are primarily on infrared sensors.

We recognize and appreciate the efforts of the Departments of Commerce, Defense, and State to rationalize, clarify, and focus U.S. export controls. RIN 1400-AD32, and the accompanying RIN 0694–AF75 revising the EAR, represent progress toward positive USML and CCL descriptions of controlled items.

We fully appreciate the value of night vision technology in defense applications, and the importance of maintaining the U.S. advantage in this area. However, commercial infrared sensors are important to many areas of scientific research, and these proposed rules represent an increase in control that would make important scientific research more difficult, or impossible, to conduct at U.S. universities. Our comments to RIN 1400-AD32 and RIN 0694–AF75 urgently recommend applying ITAR controls more specifically to military night vision items.

We offer the following comments:

1. Too many infrared sensors required for scientific research would be subject to ITAR control.

RIN 1400-AD32 and the complementary RIN 0694–AF75 would mean that devices required for scientific research would be subject to increased ITAR control, and that some EAR-controlled devices already in use would become ITAR-controlled. Use of ITAR-controlled devices at U.S. universities is problematic, since use by any non-U.S. student, researcher, or faculty member could be seen as an ITAR "defense service" or the transfer of ITAR "technical data". Exporting for use in scientific installations outside the U.S., such as astronomical observatories, becomes more difficult as well. Devices already in use may change jurisdiction from EAR to ITAR, resulting at minimum in uncertainty and confusion and potentially stopping important research.

This is particularly troubling in light of the October 2012 ***Critical Technology Assessment: Night Vision Focal Plane Arrays, Sensors, and Cameras***[1], which had concluded that:

- "Military-use-only night vision components and equipment have different physical and technical characteristics than dual-use night vision components and equipment (e.g., weapons mounting, stability software, special packaging), which could be used as a discriminator in controlling items on the USML and CCL
- "Uncooled infrared FPA size is not an indication of military application
- "IIT Generation is not an indication of military application
- "There is widespread availability of night vision components and equipment among Wassenaar Arrangement regime members.
- "There is evidence that certain items across all types of night vision components and equipment are available from outside of regime members. These countries include Belarus, China, India, Israel, Singapore, and Taiwan.
- "There is clear evidence that foreign availability exists outside of regime members at all size ranges for uncooled FPAs, uncooled cameras, and IIT imagers."

Infrared sensors are important scientific research tools, used across a wide range of disciplines including astronomy and space science, telecommunication, photonics, computer processor-memory interconnects, materials engineering, thermal management, energy storage, energy conversion, photovoltaic devices, groundwater management, computational ophthalmology, and molecular medical diagnostic tools.

The proposed rules would disadvantage U.S. researchers in all of these scientific areas compared to their counterparts in other countries, by forcing them to either prevent highly qualified non-U.S. researchers from participating in research at U.S. universities, or use inferior instruments.

This U.S. research disadvantage would be reduced by controlling non-military infrared sensors under the EAR. We could further enable valuable U.S. scientific research by recognizing that use of an infrared sensor in domestic scientific research doesn't generally result in a transfer of information or a service that requires control and licensing.

MIT strongly recommends revising the scope of ITAR control of infrared sensors in line with the above findings.

2. XII(c)(2)'s "catch" is too broad, and its "release" too narrow

The preamble to the proposed rule states "With minor exceptions, all bare (Infrared Focal Plane Arrays) IRFPAs are controlled in Category XII, paragraph (c)(2)", unless they are "incorporated into a permanent encapsulated sensor assembly", in which case they are either controlled in (c)(3)-(c)(6) or subject to the EAR. This states that any bare IRFPA system is ITAR controlled, whether it's an old commercial device or a cutting-edge military device.

[1] https://www.bis.doc.gov/index.php/forms-documents/doc_view/630-night-vision-assessment

We disagree with the preamble's assertion that "paragraphs (c)(3)-(c)(6) … parameters are set at a level that the Department has determined excludes most commercial products". The XII(c)(4) criterion controlling "two-dimensional photon detector IRFPAs…having greater than 256 detector elements" is such a low threshold that virtually all devices useful to scientific research would be included. A published 2012 table of "representative IR FPAs offered by some major manufacturers" listed 30 photon detector IRFPAs from 8 manufacturers (4 U.S., 4 non-U.S.), with 110,592 to 16,777,216 detector elements, that would easily qualify for control under XII(c)(3)[2].

MIT recommends:

- Revising the control parameters in the proposed XII(c)(3)-(c)(6) in the context of current commercial availability so that they will exclude most commercial products.
- Revising XII(c)(2) to control only IRFPAs that in sensor assembly form would be controlled under XII(c)(3)-(c)(6).

3. XII(c)(2)'s reliance on "permanent encapsulated sensor assembly" as a control parameter

We appreciate that "permanent encapsulated sensor assembly" is in the spirit of "positive lists". However, it's apparently intended to prevent any possible transfer of technical data requiring ITAR control through inspection of XII(c)(2) IRFPAs. There is no discussion or representation in the preamble of how much, or what kind, of technical data might be subject to transfer through inspection. We are skeptical that substantial information required to develop or produce IRFPAs is transferred through inspection of the physical device. For older and low-performance devices, it's even less likely that useful information is transferred through inspection.

There is also no discussion or examples of acceptable "permanent encapsulated sensor assemblies" for IRFPAs, or reference examples for other devices. Existing devices which were manufactured without permanent encapsulated sensor assemblies, which could be all devices manufactured to date, would become ITAR-controlled whether they are currently controlled under the EAR or the ITAR. This would be disruptive to U.S. scientific research, as universities would have to choose between removing qualified researchers from ongoing projects or replacing newly ITAR-controlled devices with inferior technology at substantial cost.

MIT recommends:

- Identifying specific development or production technology that might be transferred through inspection of physical IRFPAs, and focusing controls on the identified technology.
- Identifying specific commercially available items that represent examples of acceptable "permanent encapsulated sensor assemblies".
- Provide an exception to the "permanent encapsulated sensor assembly" criterion for products already on the market.

[2] Antoni Rogalski, "Progress in focal plane array technologies", Progress in Quantum Electronics 36 (2012): 405

4. Technologies already commercially available outside the U.S. should not be ITAR-controlled

Companies like Sofradir (France) and Xenics (Belgium) produce bolometer and photon detectors IRFPA devices, some of which are controlled under the current USML Category XII and more of which would be controlled under the proposed rule.

Charge multiplication FPAs are currently available at 1024 x 1024 elements (Andor[3]) and 1392 x 1040 (Photonic Science[4]), companies outside the U.S. providing electron multiplying charge coupled devices for scientific, non-military-related research. Devices surpassing 1,600 elements in one or more dimension are expected in the near future, and would become subject to XII(c)(7) in the U.S.

When these items are more restricted in the U.S. than in their country of origin, it makes it more difficult for U.S. researchers to use them for legitimate non-military scientific research without making them unavailable to potential adversaries.

5. Funding source should not determine export control jurisdiction

XII(b)(14) "catches" developmental laser systems, and XXII(c)(14) "catches" developmental imaging systems, as subject to the ITAR if funded by the Department of Defense unless specifically "released" as being developed for both civil and military applications in the contract or funding authorization. This requires the contracting officer to have awareness of the possible end uses of the technology being developed, and to make a positive assertion to that effect in the documentation, setting up a dynamic where the default will be ITAR control. In our experience, contract officers are not expert at interpreting the export control regulations, and should not be making federal policy. Projects conducted at an accredited US research institution should be considered fundamental research unless the project is specifically classified, as directed in NSDD-189.

Much basic and applied research in these areas, as conducted at universities, is based on public domain information, conducted by universities, and may be sponsored under Department of Defense 6.1 (basic research) or 6.2 (applied research). It's possible that "developmental" is intended to have a meaning completely disjoint from "basic and applied research", but this has not been explicitly stated.

MIT recommends:

- Determination of jurisdiction should be made through the USML and the CCL, not by funding source.
- Jurisdiction for emerging technologies that have not yet been evaluated for possible inclusion on the USML or CCL should be made for those technologies on an as-needed basis, in consultation with a DOD office or person with export control expertise and able to resolve disputes.

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[3] http://www.andor.com/scientific-cameras/ixon-emccd-camera-series

[4] http://www.photonic-science.co.uk/products/PDF/Intensified_cameras.pdf

MIT appreciates the opportunity to provide DDTC with the above comments on RIN 1400-AD32.

Sincerely,

Maria T. Zuber

Linda Dempsey

Vice President
International Economic Affairs

July 6, 2015

Mr. Kenneth Handelman
Deputy Assistant Secretary of State for Defense Trade Controls
Bureau of Political-Military Affairs
U.S. Department of State
Washington, DC 20522-0112

Re: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII (RIN 1400-AD32)

Via e-mail: DDTCResponseTeam@state.gov

Mr: Handelman:

The National Association of Manufacturers (NAM) welcomes the opportunity to comment on amendments to the International Traffic in Arms Regulations (ITAR) to revise U.S. Munitions List Category XII (Fire Control, Range Finder, Optical and Guidance and Control Equipment).

The NAM is the nation's largest industrial trade association, representing small and large manufacturers in every industrial sector and in all 50 states. Our members play a critical role in protecting the security of the United States. Some are directly engaged in providing the technology and equipment that keep the U.S. military the best in the world. Others play a key support role, developing the advanced industrial technology, machinery and information systems necessary for our manufacturing, high tech and services industries.

The proposed amendment would control under the ITAR many high-technology items – infrared, night vision, lasers, optics and gyro-stabilized gimbals – that are widely available outside of the United States, in countries that control those items as commercial. We witnessed profound damage to the U.S. industrial base when similarly restrictive controls, with similarly broad foreign availability, where placed on the commercial satellite industry. Therefore, we urge the State Department to substantially revise the proposed rule to more appropriately control as commercial those items that are available from foreign sources and controlled as commercial by the foreign country where it is manufactured.

One of the primary objectives of the Export Control Reform Initiative, as outlined by President Obama and then-Defense Secretary Robert Gates in 2009, was a focus on controlling truly sophisticated and sensitive military articles and technology that allowed for shifting less sensitive items to the control of the Commerce Department – a policy of placing "higher walls around fewer things." The proposed changes to USML Category XII, however, would control as military many infrared, laser and optics items that are commercial or dual-use. Moreover, these items are available from foreign sources in countries that control those items as commercial. The proposed rule would severely limit the ability of manufacturers in the United States to compete in the global market for these high-tech items. Companies in China, France, the United Kingdom, Germany, Slovenia, Italy, Japan, Canada, Turkey and elsewhere would reap the benefits if U.S. exporters abandon the global commercial markets for these items.

A joint report from the Departments of State and Defense to Congress in 2012 on the impact of shifting control of commercial satellites to the Commerce Department found that a decade of restrictive, unilateral controls on satellites weakened the U.S. industrial base while failing to protect the high-tech satellite technologies that the military requires – harming U.S. national security. Unfortunately, the proposed rule for USML Category XII echoes those mistakes.

The NAM urges the State Department to work collaboratively with its partner agencies to rewrite this proposed rule and categorize for commercial export control those items that are available outside of the United States and controlled as commercial by the relevant country. Enabling global competitiveness for manufacturers in the United States will foster growth and spur investment in R&D to ensure the continued innovation that bolsters our national security.

Thank you for the opportunity to provide comments on the proposed rule to amend USML Category XII. Manufacturers remain committed to working with the State Department and other U.S. agencies to improve and streamline U.S. export control requirements that will promote U.S. economic, national security and foreign policy interests.

Thank you,

Linda M. Dempsey

Linda Dempsey

LMD/la

NDIA
National Defense Industrial Association
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July 1, 2015

Mr. Kenneth Handelman
Deputy Assistant Secretary of State
for Defense Trade Controls
Bureau of Political-Military Affairs
U.S. Department of State
Washington, DC 20522-0112

SUBJECT: ITAR Amendment—Category XII, RIN 1400-AD32, entitled "Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII"

Dear Mr. Handelman: Ken

On behalf of the more than 1,600 member companies and nearly 90,000 individual members of the National Defense Industrial Association (NDIA), we appreciate the opportunity to comment on proposed revisions to the ITAR related to USML Category XII, Fire Control, Range Finder, Optical and Guidance and Control Equipment. The rule proposes to control as military many items that are widely available outside the United States, in countries that all control them as commercial. These items comprise a portion of the U.S. high-technology industrial base including infrared, night vision, lasers, optics, and gyro-stabilized gimbals. Given the detrimental effect on the commercial space industrial base that similar controls have had, we fear the negative impacts these proposed controls will have on the relevant industry. We therefore ask that you rescind the proposed rule and control as commercial any item made outside the United States that is controlled as commercial by the foreign country in which it is made.

One of the main tenets of the President's initiative to reform the U.S. export control system is to "place higher walls around fewer things" by controlling sophisticated military articles and technology, while moving less sensitive items used by the military to the control of the Department of Commerce. The latter items are considered commercial or dual-use technologies. Unfortunately, the proposed changes to USML Category XII would control as military many infrared, laser, and optics items that are commercial or dual-use and available from world-wide sources in countries that already control these items as commercial.

For example, uncooled infrared focal plane arrays are presently manufactured by at least nine companies operating in seven countries outside the United States. Three of these companies are located in China. All seven of these countries control these items as commercial or dual-use. The proposed rule change would restrict only the export of products manufactured in the United States. Similarly, only U.S. manufacturers of some high intensity lasers would be restricted from exporting their products while those lasers are manufactured in several countries overseas, all of which control these items as commercial products and are able to sell them freely. The proposed changes will thus severely limit our ability to compete in the global industrial and scientific laser market, abandoning our competitive edge to companies in other countries.

These proposed rule changes, if finalized in their current form, will have a seriously detrimental impact on the U.S. industrial base, harming our national security rather than helping it. In the 2012 joint Department of Defense and Department of State report to Congress on using Commerce Department export controls for commercial satellites, the Departments stated that controlling such globally-available commercial items as military harmed the national security of the United States by weakening the U.S. industrial base while doing nothing to protect the critical satellite technologies that our military requires.

Yet this new proposed rule for USML Category XII would repeat the same mistake. It will remove these segments of the U.S. industry from the global market, conceding competition to extant foreign companies, enabling them to grow unchallenged by U.S. competition. Strong, competitive companies such as Dali and Wuhan-Guide in China, Ulis and Sofradir in France, Selex in the United Kingdom, AIM, Rofin, and Jenoptik in Germany, Le Tehnika in Slovenia, Optec in Italy, SCD in Israel, Hamamatsu and NEC in Japan, Teledyne-Dalsa in Canada, and MikroSens in Turkey will benefit from the absence of U.S. industry from these well-established commercial markets.

NDIA strongly urges a fundamental rewrite of this proposed rule to categorize items as commercial, subject to control by the Department of Commerce, if any similar items are available outside the United States and are controlled as commercial by the relevant government. It makes no sense for the United States to place walls around its industries when other countries already produce and do not control similar items. U.S. companies must have the ability to compete on a level footing.

In the end, enabling the global competitiveness of U.S. companies will foster their growth, investment in new and better technology, and strengthen the U.S. industrial base to ensure a continued stream of the best technology available for our warfighters. These factors add up to improved U.S. national security. Controlling the relevant items as the rule proposes to do will have the opposite effect without keeping these technologies out of the hands of other states, which already manufacture them in their own domestic industries.

Thank you for your attention to this letter and your service to our country. Please contact me at wgoodman@ndia.org or (703) 247-2595 with any questions you may have.

Sincerely,

[signature]

Will Goodman
Vice President for Policy

Ken:
This rule will do harm.
Please let me know how we
can work together for controls
that will protect critical technology
but also strengthen our industrial
base. Thanks, Will

From:	Curtis Sumner
To:	DDTCPublicComments
Subject:	ITAR Amendment - Category XII
Date:	Monday, July 06, 2015 5:03:04 PM

The National Society of Professional Surveyors (NSPS) is deeply concerned that the proposed ruled for Export Control Reform (ECR) with respect to fire control, range finder, optical and guidance and control equipment will have an adverse impact on LiDAR, GPS and aerial cameras used in the land surveying profession.

NSPS believes the proposed rules place new controls on certain existing commercial surveying systems and equipment products. It fails to establish a “bright line” between the military (USML) and commercial (CCL) designations, particularly for imaging, GPS and LiDAR systems. The proposed changes to USML Category XII could disadvantage our U.S. manufacturers and operators when competing for commercial applications against foreign competitors.

NSPS respectfully urges the Departments of Commerce and State not to adopt rules that could cost jobs and hamper surveying businesses in exporting, with no benefit to U.S. national security.

Sincerely,

Curtis W. Sumner, LS
Executive Director
National Society of Professional Surveyors
5119 Pegasus Court, Suite Q
Frederick, MD 21704
(240) 439-4615

From:	Ed Gillespie
To:	DDTCPublicComments
Subject:	ITAR Amendment-Category XII
Date:	Tuesday, July 07, 2015 12:00:55 AM

Subject: ITAR Amendment-Category XII

We wish to provide the following comments regarding the proposed changes to the ITAR as published in the Federal Register on May 5, 2015.

Regarding subparagraph (b), Lasers and laser systems and equipment as follows:

1. *Proposed paragraph (10):* Tunable semiconductor lasers…
   Comment: the term "tunable- semiconductor-laser" is too broad. Simple broad area lasers can be tuned by heat and simple optics. These lasers >1W are broadly used for industrial & medical applications. Our company already produces semiconductor lasers with 4W power.
2. *Proposed paragraph (11)*: "Non-tunable single transverse mode semiconductor lasers having an output wavelength exceeding 1,510 nm and either an average output power or continuous wave (CW) output power greater than 2 W";
   Comment: we propose the following revisions:
   Revise: Should only be controlled if "specially designed" for military application.
   Revise: should include "individual"; i.e., individual single transverse, to be consistent with EAR.

3. *Proposed paragraph (12)*: *Non-tunable* multiple transverse mode semiconductor lasers having an output wavelength exceeding 1,900 nm and either an average output power or CW output power greater than 2 W;
   Comment: Large commercial markets for these products today. for example: dermatology lasers;
   Such lasers are already currently producing with over 1W power and 2W power in the near future.
   Revise: Should only be controlled if "specially designed" for military application.
   Revise: should include "individual"; i.e., individual multiple transverse, to be consistent with EAR.

4. *Proposed paragraph (13)*: Laser stacked arrays as follows:
   (i) Having an output wavelength not exceeding 1,400 nm and a peak pulsed power density greater than 3,300 W/ cm2;
   (ii) Having an output wavelength exceeding 1,400 nm but less than 1,900 nm and a peak pulsed power density greater than 700 W/cm2;
   (iii) Having an outputwavelength exceeding 1,900 nm and a peak pulsed power density greater than 70 W/cm2; or
   (iv) Having an output wavelength exceeding 1,900 nm, and either an average output power or CW output power greater than 20W;
   Comment: Large commercial markets for these products today. We believe such arrays are

already in production in Europe.
Comment: need better definition for stacked array – should follow specific definition in EAR.
Revise: Should only be controlled if "specially designed" for military application.

5. *Proposed paragraph (14)*: Developmental lasers and laser systems or equipment funded by the Department of Defense; **Note 1 to paragraph (b)(14):** This paragraph does not control developmental lasers and laser systems or equipment (a) in production, (b) determined to be subject to the EAR via a commodity jurisdiction determination (see § 120.4 of this subchapter), or (c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications.
Comment: Historically, a primary purpose of Government funded research and development program, including SBIRs and IRADs, has been to support commercialization of the technology as stated in the RFPs, yet in this company's significant experience, none have contained explicit language in the "contract or funding authorization" as being developed for both civil and military applications. From this company's perspective, whenever the question was asked, the contracting and program authorities, at the R&D level, did not know . The government typically has not applied export controls to developmental efforts, especially when the government chose not to continue the development for one reason or another. A good example would be an SBIR effort that the government chose not to fund for Phase Two or Phase Three. Therefore, this exception (c), without further guidance, is inadequate and this company requests additional clarification.

With regards,

Ed Gillespie
Contracts & Compliance Manager
nLIGHT Photonics Corporation

NORTHROP GRUMMAN

Northrop Grumman Corporation
Corporate Office

Global Trade Management
2980 Fairview Park Drive
Falls Church, VA 22042

July 1, 2015

Department of State
Bureau of Political-Military Affairs
Department of Defense Trade Controls
2401 E Street, N.W.
12th Floor, SA-1
Washington, D.C. 20522

ATTN: Mr. C. Edward Peartree
Director, Defense Trade Controls Policy

SUBJECT: ITAR Amendment – Category XII [FRN 2015–09673 (RIN 1400–AD32)]

Dear Mr. Peartree:

Northrop Grumman Corporation (NGC) wishes to thank the Department for the opportunity to submit comments in review of the above proposed rules as we support the Department's objective of establishing a positive United States Munitions List (USML). In response, NGC provides the following:

General:

Definition of "Equipment" and its use in Cat XII (and other categories). The current definition of "equipment" needs to be better defined as currently "equipment" can be practically anything and everything including any combination of the listed entries in 120.45 (a)-(g). "Equipment" can be an end-item, subset of an end-item component, accessory, attachment, firmware or software. The use of term "equipment" as proposed in this rule, and throughout the USML, is actually redundant and created uncertainty as it is always paired with the terms "systems" or "components, accessories, and attachments."

NGC, therefore, recommends adding meaning and distinction to the term "Equipment" by aligning the ITAR definition of "Equipment" with that in the CCL "B" group

SME classification for parts, pieces, and components. We recommend parts, pieces and components only be enumerated or described in XII(e) and the "*" SME designation be removed from the XII(a), (b), (c) & (f) major paragraphs. SME designation should only be placed on individual subparagraphs as appropriate and consistent with SME controls for systems, parts, and components, etc. found in other USML categories. For example, *XII(a)(1) enumerates fire control systems, but now also controls formerly XII(e) specially designed parts and components as SME. Helmet mounted display systems for a combat vehicle are designated SME in XII(a)(9); however, if the helmet mounted display is for an aircraft it is not designated SME in VIII(h)(15).

Order of Review. One purpose of ECR was to create bright lines for unambiguous classification of articles; however, similar/same technologies continue to be described in multiple entries in addition to being subject to various “catch-all” paragraphs on the USML (e.g. fire control systems). At the same time, an article can also have multiple capabilities which meet the criteria in multiple entries, even in different categories, creating conflict and difficulty in classifying the article. By definition every system with a cooled thermal imager meets the requirements of multiple sections of the proposed rule.

We first recommend reconciling and eliminating duplicate/overlapping entries where ever possible in the USML;.

Next, an order of precedence/review is necessary for USML categories where conflict/overlap remains between air, land, sea, and space systems and their Cat XI and XII components. Category XI currently defers to Cat XII by clarifying “Electronic equipment and systems not included in Category XII of the U.S. Munitions List,” but there are still other instances which need to be reconciled. We recommend XI and XII take precedence over other USML categories with exception of possibly Cat XV For example, gyroscopes are described in Cat XII(d)(3), but also in Cat XV(e)(13) Control moment gyroscope (CMG) specially designed for spacecraft. We recommend the USG add similar language as found in XI(a) as necessary to provide clear guidance if XV takes precedence. For the remaining categories we recommend adding “not included in Category XI or XII of the USML” to other categories as follows:

> Cat VI(f) Vessel and naval equipment, parts, components, accessories, attachments, associated equipment, and systems <u>not included in Category XI or XII of the USML</u>, as follows:
>
> Cat VII(g) Ground vehicle parts, components, accessories, attachments, associated equipment, and systems, <u>not included in Category XI or XII of the USML</u>, as follows:
>
> Cat VIII(h) Aircraft parts, components, accessories, attachments, associated equipment and systems, <u>not included in Category XI or XII of the USML</u>, as follows:
>
> Cat X(a) Personal protective equipment, <u>not included in Category XI or XII of the USML</u>, as follows:
>
> Cat XX(c) Parts, components, accessories, attachments, and associated equipment, including production, testing, and inspection equipment and tooling, specially designed for any of the articles in paragraphs (a) and (b) of this category and <u>not included in Category XI or XII of the USML</u>, (MT for launcher mechanisms specially designed for rockets, space launch vehicles, or missiles capable of achieving a range greater than or equal to 300 km).

<u>Paragraph *(a) Fire control, weapons sights, aiming, and imaging systems and equipment:</u>

(1) Fire control systems. We recommend control of these systems regardless of end use platform (air, land, or sea) under Cat XII and not designated SME. Fire control systems are proposed to be controlled without caveats or exclusion and their specially designed components, as SME, in Cat XII(a)(1). However; fire control computers, stores management systems, armament control processors, etc. are currently non-SME controlled in USML Cat VI(f)(6), VII(g)(12), VIII(h)(16), and also in the catch-all XX(c). Recommend implementing the order of review proposal above and removing and reserving as necessary to control all fire control systems, etc. under one USML entry.

(9) Helmet mounted display systems. Recommend removing and reserving USML Cat VIII(h)(15). Cat XII(a)(9) should control all these devices based on stated performance parameters and not on end use. Also recommend these not be SME controlled as they are not SME controlled in Cat VIII(h)(15).

<u>Paragraph *(b) Lasers, and laser systems and equipment:</u>

(b)(1) Laser target designators. Recommend defining in terms of performance parameters what constitutes a USML laser target designator.

(b)(13)(i) Laser Stacked Arrays. The threshold is too restrictive as devices capable of exceeding the 3300W/cm^2 peak power limit are easily found in the current commercial market. We suggest either a significant increase in the limit or additional language that speaks to the average power of the devices would be better. Recommend only diode arrays that can produce this peak power at average powers of more than 500W/cm^2 to be subject to the ITAR.

<u>Paragraph *(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores:</u>

(c)(2) Photon detector, micro bolometer detector, etc. Recommend further definition/clarification as to what constitutes an "encapsulated sensor assembly."

(c)(4) Two-Dimensions photon detectors, etc.. Recommend clarification if "greater than 256 detector elements" refers to the total number of elements or the number of elements in either direction.

(c)(13) Binoculars, etc. Recommend the USML Cat X(a)(7) optical articles and their part and components in X(d)(2)-(3) be combined and/or reconciled with similar items/technologies proposed in XII(c)(13) and XII(e)(9).

<u>Paragraph (d) Guidance, navigation, and control systems and equipment:</u>

Inertial sensor and systems nomenclature. Recommend that inertial sensor and systems nomenclature reflect designations in the 2010 DoD "Policy for International Transfer and Export Control of Inertial Navigation Systems, Gyroscopes, Accelerometers' Other Systems and Related Technology" and the CCL Category 7; namely, Accelerometers; Gyroscopes; Airborne INS; Land INS; Marine INS; IMU and AHRS. Rationale: a consistent nomenclature would be extremely helpful to industry and the government in relating one classification to another and driving consistency among various requirements. It is also recommended the USG work toward aligning all USML, CCL, DoD Policies, MTCR and license proviso nomenclatures.

Note to paragraph (d)(1). We recommend deleting "Note to paragraph (d)(1)" as well as removing and reserving USML Cat IV(h)(1), Cat VI(f)(4) & Cat III(c)(1). This would place controls for the same/similar technology for all guidance, navigation and control systems in XII(d) verses multiple USML categories. Navigation systems was already removed from Cat XI and this proposed rule already removes and reserves USML Cat VIII(e) which is also referenced in the “Note to paragraph (d)(1).”

Note 1 to paragraph (d)(2). We recommend deleting “Note 1 to paragraph (d)(2).” All accelerometers (other than possibly Cat XV) should be controlled in this category. USML fuze accelerometers should be controlled in XII(d)(2) verses III(d) or IV(h) for same rationale above.

Also recommend adding notes to paragraphs III(d) IV(h) redirecting to XII(d) for accelerometer fuzes, as follows:

> Cat III(d)(2) Safing, arming and fuzing components (including target detection and localization devices) for the articles in paragraph (a) of this category; and
>
> Note to paragraph III(d)(2): For weapon fuze accelerometers, see USML Category XII(d).
>
> Cat IV(h)(25) Fuzes specially designed for articles enumerated in paragraph (a) of this category (e.g., proximity, contact, electronic, dispenser proximity, airburst, variable time delay, or multi-option) (MT for those fuzes usable in systems enumerated in paragraph (a)(1) of this category);
>
> Note to paragraph VI(h)(25): For weapon fuze accelerometers, see USML Category XII(d).

Note 3 to paragraph (d)(2). Recommend adding a note or clarifying the measurement of ‘bias’ and ‘scale factor’ refer to one sigma standard deviation with respect to a fixed calibration over a period of one year.

Product line performance. Recommend a note be added to clarify how the performance levels should be applied. Are these performance level against the product line or against each system? It is recommended that performance levels be applied against the product line because there could be instances in which specific items from a product line would fall under USML CAT XII and other items from that product line falling under CCL Category 7. This could result in significant confusion and increase per unit cost for US suppliers. Recommend using the certification methodology from the DOD Policy as well.

Performance parameters. Recommend that performance levels for USML Category XII be harmonized, in general, accepting some specific exceptions, with “Policy for International Transfer and Export Control of Inertial Navigation Systems, gyroscopes, Accelerometers’ Other Systems and Related Technology.” Rationale: the DoD has already established that these levels of performance are of interest for control. Maintaining consistency between the DoD Export Policy and the USML would eliminate potential confusion. Recommend the following performance parameters:

Gyroscope: 0.0005deg/√Hr

> Recommend lowering the gyro Angle Random Walk performance value from 0.00125 deg/√Hr to 0.0005 deg/√Hr to better align the gyro with the accel and INS performance values. Angle Random Walk is clearly defined by the industry by invoking the Allan

Variance. Rationale: this performance parameter is unambiguous and its value is more consistent with the levels specified for the accelerometer control.

Accelerometers: 10 µg and 10 ppm

Using the term uncertainty rather than stability provides somewhat better clarity is how to define the terms. Note: Defining "uncertainty" and linking that to "stability" in the CCL is required to avoid confusion.

INS: Airborne INS 0.28 nmph CEP; at a 1 hour period

Land INS 0.28 mrad secant (Lat)

Marine INS 0.2 nm in 8 hour period, CEP

Providing distinct performance parameters for INS configured for airborne, land and marine applications will be easier to both industry and government to understand what is covered by Category XII. Also recommend inserting a statement that INS performance is without position aiding devices

IMU: Gyroscope and accelerometer parameters or airborne INS value

Since industry has two ways in which to describe an IMU; as the performance of the gyros and accels, which make up the IMU or as an equivalent INS performance expressed in nmph CEP. With the proposed USML performance values, this would result in a bit of an asymmetry since the gyro performance levels are more consistent with an 0.8 nmph CEP performance, thus changing to the proposed gyro performance would provide the proper balance.

Given the performance parameters above, we recommend removing USML paragraph entry XII(d)(1)(iii) eliminating the "or 25 g" performance requirement. Rationale: Assuming that the objective of Category XII is to control inertial performance of strategic value while letting the lower performance inertial be controlled by the CCL. The 25 g "or" condition will result in lower performing inertial systems remaining under USML. Defining performance levels consistent with the DoD Export Policy is sufficient to maintain the intent of the control.

<u>Paragraph (e) Parts, components, accessories, attachments, and associated equipment:</u>

(9) Infrared lenses, mirrors, etc. Recommend removing and reserving this entry and controlling these lesser items if "specially designed" on the CCL. Otherwise, recommend providing performance thresholds control parameters for each.

(10) & (11) Signal or image processing electronics. Recommend these items be placed under XI(b), or remove and reserve XI(b), or define/reconcile what is controlled between these USML entries.

(11)(i) Automatic or aided detection etc. Recommend all these term be defined, including the threshold for what constitutes a "military or intelligence" item. Does the recognition/classification of a generic "man", "truck" or "plane" which can be performed by commercial systems meet this entry threshold or does the recognition/classification have to be a "military" soldier, a tank, or Mig-29? Being able to discriminate a commercial tanker truck or other item may not have any "intelligence" value unless combined with location or the number of trucks over a period of time.

Note to paragraph (e)(11)(ii). As currently written, it is perfectly clear that combining data from two Cat XI systems does not constitute sensor fusion and is not USML controlled. If this is the

USG intent, then leave as is; otherwise, recommend the definition for multi-sensor fusion align with DoDI S-5230.28.

Paragraph *(f) Technical data and defense services:

Notes 1, 2, & 3 to paragraph (f). As stated in the Supplementary Information of this proposed rule, "Three notes are added to paragraph (f) to address technical data and defense services when incorporating defense articles into commercial items." However, Note 2, paragraph A. makes no reference to the EAR or commercial items which makes the entire note unclear regarding applicability. Further, Note 2, paragraph A. enumerates what software and technical data is "included" in paragraph (f). It did not make any reference or enumerate any entries in paragraph (d); therefor as written, it could be perceived that manufacturing process descriptions, of USML accelerometers, gyroscopes, or INS as identified in (d) are no longer controlled as technical data (f). Recommend a complete review and revision of Notes 1, 2 & 3 to paragraph (f) with specific attention to Note 2.

Note 2 paragraph C. These items are also enumerated or described in USML Cat IX(b). Recommend removing paragraph C or make a reference note in Cat IX(b) that these items are controlled in Cat XII(f).

Software. We also agree with the DoS decision to separate "software" from the definition of "technical data." We think this is a positive step toward a single list and will make it easier to enumerate what software should be controlled as was attempted in Note 2 to paragraph (f). We will provide full comments to the 3 Jun 15 proposed rule in a separate response.

Should clarification or subsequent technical discussions be necessary, please contact either Steve Headley at james.headley@ngc.com, (703 280-4806), or myself at thomas.p.donovan@ngc.com (703-280-4045).

Sincerely,

Thomas P. Donovan
Director, Export Management
Global Trade Management

From:	Neil Gerein
To:	DDTCPublicComments
Cc:	Toby Happychuk
Subject:	ITAR Amendment—Category XII
Date:	Monday, July 06, 2015 5:42:25 PM

Dear Representative,

Please find below comments from NovAtel Inc. below on the proposed rule changes.
"With respect to paragraph(d)(7)): Civil safety-of-life and critical infrastructure GPS and GNSS applications are subject to intentional and non-intentional interference. The use of null steering antennas in these applications has been shown to be an effective mitigation strategy. The use of multiple antenna element adaptive antenna arrays that provide 45 dB of jamming margin will greatly enhance the protection of civil safety-of-life and critical infrastructure applications and should be considered subject to the jurisdiction of the EAR. The proposed amended wording of paragraph(d)(7) should read ***"GNSS anti-jam systems employing adaptive antennas that have a minimum of five antenna elements, add 45 dB or greater anti-jam margin, and produce nulls in the direction of jammers or high-gain beams in the direction of satellites at any ranging code frequency;"*** *For administrative purposes the language in paragraph(d)(7) and paragraph(d)(6)(iii) should be consolidated, and the MT designation should be removed from paragraph(d)(6)iii) for airborne applications to allow the protection of civil aviation equipment."*

Best regards,

Neil Gerein
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Submission Type: Web

PUBLIC SUBMISSION

Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0024
Comment on DOS-2015-0027-0001

Submitter Information

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Phone: (860) 264-2167
Submitter's Representative: Anthony Rallo, Esq.
Organization: Nufern

General Comment

Hello,

Attached are two .pdf files consisting of Nufern's official response to the USML Category XII proposal. One document is a response letter written on behalf of Nufern by myself, Anthony Rallo, Esq., Nufern's in-house legal counsel. A supporting schematic relevant to Section III of the letter is also attached.

Thank you for the opportunity to comment on this draft. If another comment period is afforded--as was suggested during the drafting process--we will contribute again. We are hopeful you find our feedback productive, and that the DoS considers our proposed alterations before publishing the final rule.

Should you require additional information, I will leave my contact information below. Please feel free to reach out at any time.

Sincerely,
Anthony Rallo, Esq.

Attachments

Attachment1_Nufern Comment to USML Cat. XII Proposal

Attachment2_Photonics Integrated Circuit Schematic for Pulsed Industrial Laser

NUFERN

July 6, 2015

Office of Defense Trade Controls Policy
U.S. Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

RE: RIN 1400-AD32—Public Comment Concerning Amendments to the International Traffic in Arms Regulations—Revision of U.S. Munitions List Category XII.

Two Whom It May Concern:

Please accept this letter from Nufern in response to the request for public comment on the proposed revisions to Category XII of the United States Munitions List (USML), published by the U.S. Department of State under RIN 1400-AD32 [public Notice: 9110]. Category XII concerns Fire Control, Range Finder, Optical and Guidance and Control Equipment.

Nufern—a wholly owned subsidiary of Rofin Sinar Technologies Incorporated—is a U.S. company incorporated in Delaware and operating out of East Granby, CT. Nufern specializes in the manufacture of optical fibers, fiber lasers, and other optical components. Roughly 85% of Nufern's annual revenue is generated through the manufacture and sale of industrial fiber lasers and components used for marking, cutting, and welding applications; the remaining 15% is generated from defense technology. As such, the control parameters enumerated in the USML Category XII proposal directly impact the production and trade strategy of Nufern, and we appreciate the opportunity to participate in a dialogue about these parameters.

At the outset of this discussion, we would like to be clear that we accept the necessity of non-proliferation policies. We are of the position that stringent export controls for significant and critical military commodities are essential national security measures, and disagree with more radical activists that support dismantling the U.S. export regime entirely. Perhaps more significantly, we believe that national security is of priority importance among the other significant policy considerations in contemporary America. In a contest between the two, national security concerns justifiably outweigh our own interests in obtaining the most favorable regulatory infrastructure for the U.S. industrial base.

Our standard business practices corroborate our altruistic national security disposition. We invest heavily in export compliance and information control, and categorically refuse to do business with foreign militaries and suspect entities unless authorized by relevant U.S. Agencies. We maintain a corporate culture of non-proliferation, by prioritizing strict compliance with national security policies over all transactions.

We comment on the Cat. XII proposal not because we disagree that national security policies trump policies that favor U.S. industry, but because we believe that pro-industry policies frequently *are* pro-military policies, and that the tension between the two is exaggerated. We believe that overregulating export makes technological advances in the U.S. occur less frequently than is necessary, and we believe that our own contributions to the U.S. military advantage would be more significant if the ITAR more narrowly delineated certain control parameters.

The breadth of the ITAR, and the manner in which it encumbers international trade, shapes the R&D trajectory of Nufern's Industrial Laser Group and Defense Laser Group. Where collaborative R&D might otherwise produce cross-functional cost and production efficiencies, Nufern deliberately avoids synergistic development opportunities to ensure that overlapping product lines do not inadvertently trigger ITAR jurisdiction. Institutional compartmentalization of this nature diminishes the developmental sophistication of industrial products, and reduces the investment resources available for future industrial and defense innovation.

President Obama's Export Control Reform Initiative (ECR) is a welcome effort to streamline licensing procedures, clarify control parameters, and ensure that the ITAR encumbers only the technologies "that provide a critical military or intelligence advantage." Nufern has long believed that the well intentioned—and probably once justified—U.S. export control regime is wrought with ambiguity and redundancy, and therefore supports measures to both clarify the scope of export controls, and increase the ease of compliance therewith.

Like the Department of State, Nufern believes the Department of Commerce is well equipped to monitor the trade of less-critical technologies, regardless of whether those technologies have potential or primary military applications. To this end, Nufern encourages the Department of State to shift the non-proliferation effort to the Department of Commerce for all commodities and information except those which are classified, and those clearly defined commodities of critical military significance. A discussion of particular Paragraphs of the Cat. XII proposal that should be amended to narrow the scope of the USML follows.

I. Developmental Funding

A limited scope for the ITAR was promised at the outset of the ECR initiative. Department of Defense Secretary Robert Gates pledged to build "a system where higher walls are placed around fewer, more critical items." To justify his disposition, Secretary Gates cited resource inefficiencies at the DOS and DOD caused by stringent policing of insignificant commodities. The resources of both Agencies were better slated for focusing on material threats instead of enforcing arcane controls over fully proliferated or obsolete technologies. The cause of the imbalance was twofold: 1) broad and unclear provisions subjected more technology to the ITAR than was intended or justified; and 2) outdated provisions captured technologies that were no longer in need of stringent non-proliferation policies.

With ranking policymakers aware of the pitfalls of poorly defined control parameters, and mandates from those officials to bring clarity and usability to the regime, it is peculiar that certain provisions of USML Category XII have been proposed so broadly. First, and absolutely foremost, the developmental funding language found throughout the draft is a precarious regulatory mechanism for U.S. manufacturers. In the USML Category XII proposal, Paragraphs (b)(14), (c)(21), and (d)(9) respectively subject all lasers, imaging systems, and navigation equipment funded by the U.S. Department of Defense to the ITAR.

The unqualified enumeration of all items built with DoD money is unjustifiably broad. This is particularly true in light of the "Request for Comments" prompt that claims USML Category XII exclusively controls "Items...that provide a critical military or intelligence advantage." Although the nature of the DoD's role suggests that most items the DoD funds are intended to have military applications, DoD contributions do not necessarily guarantee that the development process will yield a military-grade product—let alone a product possessing capabilities that are *critical* to the U.S. military and technological advantage.

The ECR aims to transform the USML from a collection of vague 'catch-all' provisions to a clear and user-friendly positive list. On the backdrop of this mandate, promulgating a baseline presumption that all DoD funded projects will result in deliverable, working, critically important military products is untenable. It is unreasonable to assume that the DoD and development firms are capable of previsioning all possible applications of undeveloped products, especially in the technologically sophisticated field of optics. Scientific, engineering, and manufacturing principles applicable to the design and manufacture of civil or dual-use products are learned during product development in any industrial sector, and unforeseen applications are frequently discovered during development and subsequent use. The DoS should not preemptively restrict technology that is yet to be developed, regardless of funding sources.

Policymakers have cited the notes to Paragraphs (b)(14), (c)(21), and (d)(9) to downplay industry concerns about the breadth of the developmental funding language. Note 1 to all three Paragraphs provides three exceptions to the developmental funding rule: 1) items in production (presumably at the time funding is received); 2) items subject to the EAR per a 15 CFR 120.4 adjudication; and 3) items specifically enumerated as DoD items in the development contract. The first two exceptions are reasonable if the USML is a positive list, as items in production, items adjudicated to be subject to the EAR, and dual use items would not generate ITAR jurisdiction simply because of DoD procurement. The contract exception, however, is a disingenuous concession to U.S. industry.

Although it is conceivable that tier one defense primes may be able to secure express 'dual-use' language in DoD contracts, smaller subcontractors are often unable to earn the contract carve-out during contract discussions. This is due to a lack of bargaining power and the existence of one or more upstream contractors that insulate the DoD from affected subcontractors. DoD contracts are negotiated between the prime and the U.S. Government before subcontracts are executed. Subcontracts are therefore wrought with flow-down provisions that subcontractors must accept or forego the business opportunity. If a subcontractor desires to see dual-use language in a contract that is already closed, s/he is at the mercy of the prime to reopen negotiation with the DoD. In many cases, the primes and the DoD are unwilling to reopen negotiation because the regulatory status of the deliverable is often of little concern to both parties.

In open committee meetings, policymakers have dismissed this complaint by noting that the lack of appreciation for the value of 'dual-use' contract language to downstream subcontractors suggests there are implementation problems rather than problems with the regulations. This position is unreasonable. A substantively prohibitive regulation and a well-intended regulation that is implemented in a prohibitive manner are equally preclusive to the burdened parties. Similarly, a regulator who knowingly promulgates an unduly burdensome regulation and a regulator who knowingly promulgates a regulation that will be implemented in an unduly burdensome manner are equally responsible for the hardship of the affected parties.

Simple amendments to the developmental funding language would offer relief to industry without threatening non-proliferation efforts. Suggestions of such amendments follow:

- Include a *de minimus* exception for marginal DoD contributions. In many cases, companies, including Nufern, would accept DoD funding when researching defense technology would supplement research in the civil sphere. If marginal DoD contributions render all devices, even civil devices borne of industrial R&D projects, subject to the ITAR, businesses will be reluctant to conduct research for the DoD. A *de minimus* exception set at ~20% would allow smaller companies to control the trajectory of the research they primarily fund privately, while still finding value in contributing to the development of technologies with defense applications;

- Add the "specially designed" mechanism to the DoD funding provisions as follows:
    - "Developmental lasers and laser systems or equipment specially designed for the Department of Defense, or specially designed for incorporation or use with projects funded by the Department of Defense;" or

- Include a Note to Paragraphs (b)(14), (c)(21), and (d)(9) promulgating exceptions for articles incorporated into items subject to the EAR. This exception should be substantively similar to the exceptions promulgated under Note 2 to Paragraph (c) and Note 1 to Paragraph (e).

A final comment concerning the developmental funding provisions. Note 2 to Paragraphs (b)(14), (c)(21), (d)(9) can be interpreted, and perhaps is intended, to effectively foreclose any benefit provided by any of the Note 1 exceptions. Analytically, the developmental funding language and the two subsequent notes read as follows:

- (b)(14)/(c)(21)/(d)(9):
    - Items funded by the DoD are defense articles enumerated on the USML and are therefore subject to the ITAR

- Note 1:
    - Notwithstanding the rule that items funded by the DoD are defense articles enumerated on the USML, the following items are not subject to the ITAR even if purchased or funded by the DoD: (i) items that were in commercial production prior to DoD procurement, (ii) items that have been adjudicated as subject to the

EAR under § 120.4, and (iii) contractually specified dual-use items. Accordingly, although items funded by the DoD are defense articles enumerated on the USML, any item funded by the DoD which satisfies one or more of the three exceptions is not subject to the ITAR.

- Note 2:
  - Notwithstanding the fact that Note 1 excludes defense articles enumerated on the USML from the ITAR under three circumstances, no defense article enumerated on the USML may be excluded from the ITAR under Note 1 if it is a defense article enumerated on the USML. Since items funded by the DoD are defense articles enumerated on the USML under Paragraph (b)(14)/(c)(21)/(d)(9), no items funded by the DoD may be excluded from the ITAR under Note 1.

To remedy this analytical cycling, the DoS should strike Note 2 to Paragraphs (b)(14), (c)(21), and (d)(9) entirely. In the alternative, Note 2 to each Paragraph should read as follows:

- "Excluding items enumerated under Category XII(b)(14)/(c)(21)/(d)(9), Note 1 does not apply to defense articles enumerated on the U.S Munitions List, whether in production or development."

II. LIDAR

Paragraph (b)(6) controls LIDAR and LADAR systems specially designed for use with defense articles. The Note to Paragraph (b)(6) excludes from the (b)(6) controls LIDAR systems for civil automotive applications with a range of 200m or less. We agree with this exception as LIDAR systems will be utilized in self-driving automobiles for individual civil use. We believe, however, that this same exception should be extended to LIDAR systems with a range of 2.5km or less for civil avionics applications. This would promote the civil UAV industry that—among other unforeseen civil applications—promises effective delivery networks for consumer goods.

III. Tunable and Non-Tunable Semiconductor Lasers

Paragraphs (b)(10)-(12) enumerate tunable and non-tunable semiconductor lasers at certain wavelengths and power outputs on the USML. Although the powers enumerated in the Category XII proposal are stronger than those currently used in most civil systems, optics manufacturers are actively researching the use of semiconductor lasers in industrial laser systems with the hopes of standardizing the practice in the near future. Semiconductor lasers with associated photonics integrated circuitry promise manufacturing efficiencies—particularly pertaining to labor costs—that are essential for U.S. laser manufactures to compete against aggressive pricing set by competitors in countries with fewer labor protections than those afforded by the United States. Controlling all semiconductor lasers at any wavelength/output will result in undue competitive hardship to U.S. manufacturers, and will unnecessarily preclude both research and production.

For reference, a schematic for a semiconductor laser and associated photonics integrated circuitry incorporated into a pulsed industrial laser is attached to this comment.

To avoid hindering the development of semiconductor lasers for industrial applications, the DoS should include a Note to Paragraphs (b)(10-12) promulgating exceptions for articles incorporated into items subject to the EAR. The exceptions should be substantively similar to the exceptions promulgated under Note 2 to Paragraph (c) and Note 1 to Paragraph (e).

IV. LASER STACKED ARRAYS

Assuming "Laser stacked array" refers to vertically and horizontally stacked power diodes, we agree with the parameters articulated in Paragraphs (b)(13)(i)-(iii) in that they articulate reasonable power densities at certain wavelengths which suggest exclusively military usability—at least at this particular moment. We are uncertain, however, how the DoS defines "Laser stacked array" for purposes of this provision, as it is not defined in this Paragraph or in the definitional section of the Category XII proposal. We are hopeful the DoS will clarify whether this Paragraph is intended to cover both horizontally and vertically stacked power diode bars, or if the scope of the term is aimed at something else entirely.

Concerning Paragraph (b)(13)(iv), Nufern currently manufactures and markets medical fiber lasers with CW output powers ranging between 35-50W at an operating wavelength of 2 microns. We are exploring whether there are medical applications for diode lasers that are insensitive to beam quality, and believe the 20W threshold is set too low for most non-cosmetic medical applications. Therefore, the 20W threshold may chill research in this arena, or may inadvertently control lasers with valuable civil medical applications. We propose two solutions:

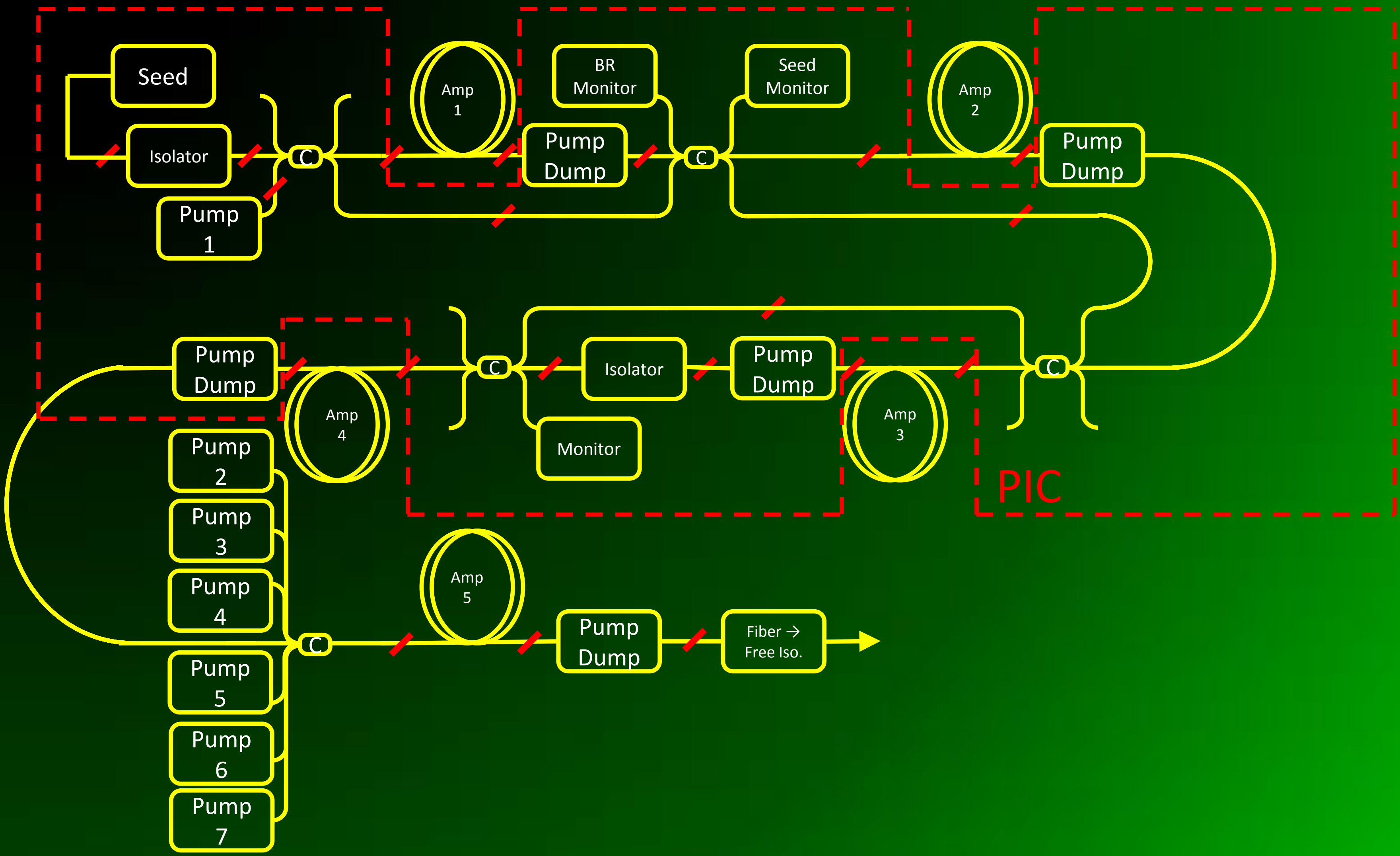
- Increase the output power threshold to 50W; or
- Include a Note to Paragraph (b)(13) promulgating an exception for articles incorporated into items subject to the EAR. This exception should be substantively similar to the exceptions promulgated under Note 2 to Paragraph (c) and Note 1 to Paragraph (e).

Thank you for considering our position on the USML Category XII proposal. We hope our feedback has been productive, and that the DoS will effectuate changes in light of our concerns. Should you have any questions or require any additional information, please do not hesitate to contact me, Anthony Rallo, Esq., at arallo@nufern.com or (860) 264-2167.

Sincerely,

Anthony Rallo, Esq.
Legal Counsel

PIC as Amplifier Core?



ON Semiconductor Corporation
5005 E. McDowell Road
Phoenix, AZ 85008

DARYL HATANO, Vice President
Government and External Affairs
Direct Line: 408-542-1176

July 6, 2015

Mr. Ed Peartree
Director
Office of Defense Trade Controls Policy
US Department of State
2401 E Street NW
Washington DC 20037

Email: DDTCPublicComments@state.gov

Re: RIN 1400-AD32
Proposed Changes to U.S. Munitions List Category XII /
Increased Controls for Night Vision Items

Dear Mr. Peartree:

ON Semiconductor is a Fortune 1000 company, with over 24,000 employees around the world generating $3.2B in revenue (2014). The company offers a comprehensive portfolio of energy efficient power and signal management, logic, discrete and custom solutions to help design engineers solve their unique design challenges in automotive, communications, computing, consumer, industrial, LED lighting, medical, military/aerospace and power supply applications. One of ON Semiconductor's key product lines, image sensors, accounts for about 19% of revenue. The context for subsequent remarks is this image sensor business.

ON Semiconductor is pleased to provide comments regarding proposed changes specific to USML Category XII as well as related changes to the EAR. These comments will pertain to its KAE-series of devices, EMCCDs (Electron Multiplication CCDs) presently controlled by the EAR via ECCN 6A002.a.3.g. We recognize that it is the intent of the Departments of Defense, State and Commerce to control items having an ability to image in low light. The proposed regulation's underlying assumption is that the selected parameters of control for charge multiplication focal plane arrays are **resolution** (number of photosensitive elements in the FPA) and **maximum radiant sensitivity** in the 760-900 nm spectral band. However in our experience the performance parameters, as defined, are unable to distinguish commercial devices from military devices or, between an image sensor using EMCCD technology and one using scientific CMOS (sCMOS) technology to deliver virtually identical or better low light imaging capability. These parameters, as defined, do not capture the lower IR sensitivity exhibited by KAE-series devices relative to sCMOS or GaAS Intensifier Tubes. The net effect of the regulations would be to hamper ON Semiconductor's ability to compete in the non-defense commercial market against foreign suppliers of EMCCD sensors and against any supplier of sCMOS sensors.

Given the rapidly growing commercial applications for low light image sensors and alternative technologies in the market, we urge that EMCCDs remain on the EAR and not be moved to the ITAR.

If EMCCD sensors must be controlled, the performance characteristics should be redefined and keyword definitions clarified in consideration of the competitive environment and intended application.

The following comments are provided employing the numbering scheme used to highlight issues of particular interest to the Department of State, as per pages 15-18 of RIN 1400-AD32.

(1) **Potential lack of coverage.**

Wassenaar appears to exclude sCMOS image sensors, known for excellent low light performance, from the regulatory framework applied to EMCCDs.

Category ML15 of the Wassenaar Munitions List (WML, dated 03-25-2015), which describes imaging equipment specially designed for military use, explicitly lists image intensifier tubes (other than first generation). Gen 3 image intensifier tubes, though in no way directly related to KAE-series image sensors in a technological sense, will serve as a benchmark later in this letter. KAE-series image sensors do not appear to be represented in ML15, nor elsewhere in the WML.

The Wassenaar Dual-Use List dated 03-25-2015 contains the following entry:

> *Note 6.A.2.b.1. does not apply to "monospectral imaging sensors" with a peak response in the wavelength range exceeding 300 nm but not exceeding 900 nm and only incorporating any of the following non-"space-qualified" detectors or non-"space-qualified" "focal plane arrays":*
> *a. Charge Coupled Devices (CCD) not designed or modified to achieve 'charge multiplication'; or*
> *b. Complementary Metal Oxide Semiconductor (CMOS) devices not designed or modified to achieve 'charge multiplication'.*

For scientific CMOS image sensors (sCMOS), developed expressly for use in low light applications, there appears to be no need to obtain export licenses. As sCMOS achieves its low light capabilities using techniques other than charge multiplication, it is treated differently—despite performing similarly. More will be presented on the noted inconsistency in subsequent comments below.

(2) **Proposed control items not controlled under Wassenaar or Dual-Use.**

No comments.

(3) **<u>USML and CCL "Bright Line".</u>**

Specifications, as well as performance in the field, show EMCCD and sCMOS image sensors to be comparable and essentially interchangeable. Yet, under the State Department proposal, U.S. exports would be controlled very differently.

Table 1 compares and contrasts two competing products used in low light imaging:

	KAE-02150 *(ON Semiconductor's CCD image sensor)*	sCMOS inage sensor *(designed, manufactured, and marketed by a U.S. subsidiary of a non-U.S. parent company)*
Resolution:	1920 x 1080 FPA	1920 x 1080 FPA
Pixel node:	5.5 micron square	6.5 micron square
Active area:	10.6 mm x 5.9 mm	12.5 mm x 7.0 mm
Charge capacity:	20,000 e-	30,000 e-
Frame rate:	60 fps (mode A); 30 fps (mode B)	100 fps (rolling shutter); 50 fps (global shutter)
Dynamic range:	68 dB (mode A); 86 dB (mode B)	>88 dB
Read noise:	9 e- rms (mode A); ~1 e- rms (mode B)	~1 e- rms
Maximum radiant sensitivity (in 760-900 nm spectral region)	95 mA/W	233 mA/W

Table 1: Comparison of specifications: KAE-02150 and competing sCMOS image sensor

On the **resolution** performance parameter the parts are identical. sCMOS is advantaged on maximum radiant sensitivity (760-900 nm), charge capacity (full well), dynamic range, and highest attainable frame rate. The parts are comparable vis-à-vis lowest attainable read noise.

Figure 1 depicts radiant sensitivity (mA/W) for the KAE-02150 and its sCMOS counterpart; the latter's capability far exceeds the former's in the spectral region cited in XII(c)(7) of the proposed U.S. Munitions List (760 nm to 900 nm, labelled "**In Scope"** in Figure 1). The reference curves also make clear that over the "In Scope" wavelengths, Gen 3 GaAs image intensifier tubes (significant from the perspective of night vision goggles) have greater radiant sensitivity than does KAE-02150.

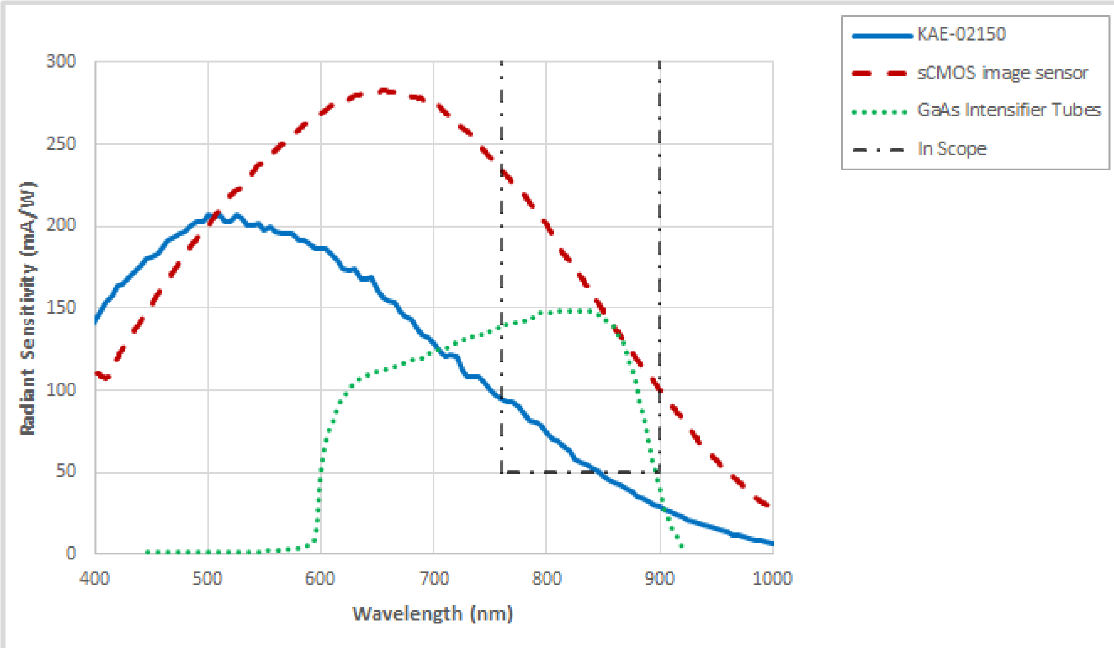


Figure 1: Comparison of radiant sensitivity curves

An analysis of Figure 1 highlights the imprudence of controlling EMCCDs under ITAR while sCMOS remains uncontrolled. Attempting to control both EMCCDs and sCMOS at the semiconductor component level is also problematic, given widespread commercial applications of such sensors as described in Section 4 of this comment, and would run counter to the overall direction of the President's Export Control Initiative.

If the State Department concludes that semiconductor image sensors must be controlled, Figure 1 suggests an alternate performance parameter which would ensure EMCCDs are not disadvantaged and widely available commercial applications of EMCCD and sCMOS are not impacted. In addition to **maximum radiant sensitivity**, the performance parameter presently cited in both the EAR and the ITAR, **average radiant sensitivity** across the spectral region of interest (ROI) could also be considered. Discussing each in turn:

- **Maximum radiant sensitivity** describes a peak value.
    - As regards the benchmark presented by GaAs image intensifier tubes, which correspond to technology used in Gen 3 night vision goggles, a maximum of 100 mA/W could safely be considered. The EAR cites a value of 10 mA/W, while the ITAR locks in on 50 mA/W.
- **Average radiant sensitivity** is calculated across the spectral region of interest.
    - This metric addresses the issue of sustained sensitivity across the spectral ROI. *In the extreme case of a single value of 100 mA/W at 761 nm (which exceeds maxima of both EAR/ITAR), and 0 mA/W across the balance of the region, average radiant sensitivity would successfully discern a virtual lack of IR detection capability.*

Both metrics cited above should be connected with logical operator AND. Thus, a curve which exceeds the **maximum radiant sensitivity** threshold AND exceeds the **average radiant sensitivity** threshold would be a candidate for control under the ITAR. Table 2 summarizes these three metrics for Figure 1 curves. Proposed language to implement this concept will be provided in Section 5 below.

Item	Peak Radiant Sensitivity *(760-900 nm; mA/W)*	Average Radiant Sensitivity *(760-900 nm; mA/W)*	Comment(s)
sCMOS image sensor	233	168	High sensitivity
GaAs IIT	149	130	Reference
KAE-02150	95	60	Low sensitivity

Table 2: Calculated values for Figure 1 traces

In addition to the quantitative metrics of Table 1, a qualitative (subjective) assessment could be incorporated. That is, KAE-02150 exhibits radiant sensitivity of less than 50 mA/W from 850-900 nm. And, as noted previously, it falls well below Gen 3 IIT performance throughout the ROI. The GaAs IIT benchmark could be useful in establishing a limit for average radiant sensitivity.

The term “avalanche detector elements” used in the State Department proposal in USML Category XII (c)(7) and XII (c)(8) (“and avalanche detector elements therefor”) requires definition. The pixel (detector element) of a KAE-02150 image sensor is identical to that for KAI-02150, a COTS EAR99 item which does not use an avalanche method or phenomenon. KAE-02150’s “charge multiplication” occurs in the readout structure, not the pixel.

(4) **<u>Examples of proposed control items that are in normal commercial use.</u>**

KAE-02150 has been licensed for, and has been designed into, a number of commercial uses, including:

- Automotive (vehicles): onboard day/night camera for road safety
- Intelligent Traffic Systems: electronic toll
- Medical: digital pathology
- Scientific: astronomy; microscopy
- Surveillance: banks; parking lots

Low light image sensor applications, including both CCD and CMOS technologies, are high-growth markets. Commercial volumes are expected to increase rapidly as costs decrease over time and advances in complementary technologies, such as the “Internet of Things” and image recognition software, increase the value of sensors. ON Semiconductor has both CCD and CMOS image sensor technologies addressing a range of light intensities, cost points, image speeds, pixel densities, and other attributes important to its customers. The company’s ability to provide a range of technologies, including EMCCD, allows it to better serve its customers as the applications for image sensing proliferate.

Commercial use of EMCCDs would be severely impacted by proposed changes in USML Category XII. Export-oriented non-defense commercial applications make up 48% of the business by customer count and 44% by revenue. Regional marketing staff estimate 90% of this would be lost under the proposed regulations (customers have cited an unwillingness to apply for ITAR export licenses). For KAE-02150, economic loss would be measured in tens of millions of dollars across the part's life cycle. An expansion of the KAE- series into a family of products would multiply losses resulting from ITAR coverage considerably.

The proposed changes in USML Category XII will have the effect of protecting foreign manufacturers of parts which would, if made in the U.S., be subjected to USML Category XII licensing requirements. Table 3 presents a pair of commercially available EMCCDs produced and sold by a non-U.S. company. Foreign suppliers of EMCCDs would be free to compete unencumbered if ON Semiconductor were not able to export due to the proposed regulatory changes.

Item	# Horizontal Pixels	# Vertical Pixels	Pixel Node *(microns)*	Comment(s)
EMCCD **A**	1600	1600	16	• Has 1,600 elements in both dimensions • 2.6 megapixels • Primary application: scientific
EMCCD **B**	4096	4096	12	• Has greater than 1,600 elements in both dimensions • 16.8 megapixels • Primary application: astronomy

Table 3: High resolution EMCCDs not subject to proposed USML Category XII

(5) **Parameters or characteristics that cover items exclusively or primarily in military use.**

Current parameters of control include "charge multiplication", resolution (number of pixels), maximum radiant sensitivity (in the 760 nm to 900 nm spectral range), and the use of avalanche detector elements. Per section (3) above, incorporation of an additional metric**—average radiant sensitivity** (in the 760 nm to 900 nm spectral range)—is urged. Judging by capability of the sCMOS device (an EAR99 item, according to the U.S.-based designer/manufacturer/seller), limits shown in Table 4 make sense from the perspective of consistency.

Metric	Suggested limit	Engineering units	Comment(s)
Resolution	None	megapixels	Non-U.S. EMCCD products are available in resolutions ranging from sub-megapixel to 1 Mp, 2 Mp, …, all the way up to 16 Mp.
Maximum radiant sensitivity (760 nm to 900 nm)	250	mA/W	Acknowledges current capability of sCMOS item
Average radiant sensitivity (760 nm to 900 nm)	175	mA/W	Acknowledges current capability of sCMOS item

Table 4: Proposed limits for metrics suggested for regulatory use

As discussed in previous sections, and in acknowledgment of the rapidly growing commercial applications for low light image sensors and alternative technologies in the marketplace, EMCCDs should remain on the EAR and not be moved to the ITAR. However, if the State Department concludes that charge multiplication focal plane arrays must be referenced in the ITAR, and the Department chooses **to synchronize its proposed Category XII language with the export status of sCMOS image sensors, <u>the suggested limits (Table 4) should be incorporated into USML XII(c)(7) as follows:</u>**

Current Department of State proposed text of USML XII(c)(7):
"Charge multiplication focal plane arrays having greater than 1,600 elements in any dimension and having a maximum radiant sensitivity exceeding 50 mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, and avalanche detectors therefor;"

Alternative proposed text of USML XII(c)(7):
"Focal plane arrays having a maximum radiant sensitivity exceeding 250 mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, and average radiant sensitivity exceeding 175 mA/W within the same spectral region of interest."

(6) **<u>Commercial items covered under Multilateral controls.</u>** No comments.

(7) **<u>Encapsulated IRFPA.</u>** The concept of a "Bright Line" between the USML and the CCL is diminished by the proposed concept of "bare" IRFPA being controlled by the ITAR, while a permanently encapsulated sensor assembly is controlled under the EAR. A permanent encapsulated sensor assembly is defined as: *"(e.g., sealed enclosure, vacuum package) [that] prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA."* Therefore goods that are in the midst of manufacture are subject to the ITAR, while goods that are in completed state are no longer subject to the ITAR. This introduces a previously unknown and unnecessarily complicated burden to the manufacturing process since a commercial part will change from the ITAR to the EAR.

The proposed regulations will have the effect of severely limiting U.S. participation in civil applications internationally. A U.S.-based manufacturer will see risks rise and rewards diminish, setting the stage for a loss of competitiveness. With KAE-series business plans under pressure, ON Semiconductor will lose not only the ability to grow and create jobs, but could find that the KAE-series business is not viable leading to the closure of this product line. This would hurt all customers, those engaged in normal commercial use as well as those looking to improve defense preparedness.

ON Semiconductor believes current export controls on EMCCDs strike the right balance between normal commercial use and national security. Further, it would seem items having similar capabilities be evaluated and controlled in a consistent fashion.

ON Semiconductor is pleased to be able to provide comments regarding the proposed changes that will directly and negatively impact ON Semiconductor. You should feel free to contact either (Daryl.Hatano@onsemi.com Tel: +1 408 542 1176), or John Frenett (John.Frenett@onsemi.com Tel: +1 585 784 5504).

Sincerely,

Daryl G. Hatano
Vice President, Government and External Affairs
ON Semiconductor

From:	W.D. Waters
To:	DDTCPublicComments
Subject:	Attempt to fully understand each issue "ITAR Amendment—Category XII."
Date:	Thursday, May 07, 2015 3:24:42 PM

Mr. C. Edward Peartree,

I would like to have made clear to me what is meant by "structures" in the proposed changes to Cat XII. Examples are cut and pasted below:

Paragraph (e)(3) is added for certain wafers incorporating structures for Read-Out Integrated Circuits (ROICs)controlled in (e)(4) or (e)(5) or for IRFPA detectors controlled in (c)(2).

(3) Wafers incorporating structures for either a ROIC controlled in paragraph (e)(4) or (5) of this category, or an IRFPA or detector elements therefor controlled in paragraph (c)(2) of this category;

Note 1 to Paragraph F

Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.

Note 2 to Paragraph F

Software and technical data include:

A. Design or manufacturing process descriptions (*e.g.,* steps, sequences, conditions, parameters) for lasers described in paragraphs (b)(6) and (b)(9) through (13) of this category, IITs controlled in paragraph (c)(1) of this category and their parts and components controlled in paragraph (e)(2) of this category (including tube sealing techniques, interface techniques within the vacuum space for photocathodes, microchannel plates, phosphor screens, input glass-window faceplates, input or output fiber optics (*e.g.,* inverter)), IRFPAs and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating structures for an IRFPA and detector elements therefor controlled in paragraph (c)(2) or structures for ROICs controlled in paragraph (e)(4) or (5)of this category, and specially designed ROICs controlled in paragraphs (e)(4) and (5) of this category (including bonding or mating (*e.g.,* hybridization of IRFPA detectors and ROICs), prediction or optimization of IRFPAs or ROICs at cryogenic temperatures, junction formation, passivation).

This information is paramount for me so that I can fully understand the regulatory document before commenting.

Regards,

--
William D. Waters
President
OptoGration Inc.
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From: W.D. Waters
To: DDTCPublicComments
Subject: Category XII real world example
Date: Wednesday, May 20, 2015 3:43:18 PM

Hello,

Below is a typical customer inquiry, please do not publish it. In order for me to quote this I would first need to find out jurisdiction. According to the new Category XII guidelines it is not clear at all if this would fall under ITAR. That being the case, I would need to file a CJR. The last one I filed took over 6 months. Since the customers timeframe is 6 months, I have no shot at the business.

I realize that your new section XII is to be more clear but to me it reads as all encompassing. Paragraph (e)(3) is added for certain wafers incorporating structures for Read-Out Integrated Circuits (ROICs)controlled in (e)(4) or (e)(5) or for IRFPA detectors controlled in (c)(2).

Our wafers can be used for IRFPAs, single element detectors, and anything in between. It seems by having this section every InGaAs based detector (every fiber to home network has one) would now be controlled under the ITAR. Can you please add some clarification. If wafers are controlled under section XII, what will happen with all of the patents? Anyone can go to USPTO.gov and see wafer designs for wafers capable of producing IRFPAs.

--
William D. Waters
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PUBLIC SUBMISSION

Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0009
Comment on DOS_FRDOC_0001-3226

Submitter Information

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Email: pkornik@neos-inc.com
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Organization: New England Optical Systems, Inc.

General Comment

I work for a small business in Marlborough, Massachusetts, by the name of New England Optical Systems. Our expertise is in the design and manufacture of infrared optical lens assemblies. These lens assemblies are used on various infrared cameras, and we have a fairly successful business inside the United States. Unfortunately, the ITAR as written has prevented us from growing to our full potential. The new proposed changes to Category XII of the munitions list will only further restrict us. By casting the wide net over all products and accessories, the ITAR goes overboard in controlling parts and products that do not pose a threat to our nations security.

There are many companies outside of the United States for whom we would like to work. These companies are located in Canada, England, France, and Germany as well as other allied nations. These companies are original equipment manufacturers (OEMs) that have camera products that require lenses. We would like the opportunity to work with these companies more freely to supply what would amount to their standard product offering. What we would be exporting would be only the lens assembly that contains infrared materials, but is not the full imaging system. It is the accessory for which the OEM would market and sell their product. Currently we are being told by companies outside the USA is that they do not want to buy any ITAR controlled items. The licensing process is too long and too inconsistent to provide them with a reliable supply base. What then happens is rather than buying a US made product, they buy from a company in Europe or

Asia.

It is very unfortunate to see the government restrict our ability to do business with established businesses in allied nations, while US companies are freely importing competing products from Europe and Asia. We simply do not have the resources to manage ITAR as well as some bigger companies can, and so we (like many others) resign ourselves that we can only do business within our borders. We are proud of what we do, and are happy that we can provide employment to some very good people. We would very much like to employ more people, but the ITAR Category XII changes will certainly limit our ability to do so. I would also like to point out that there are many very good educational institutions with students looking to get into this field. Some of these students come from outside the United States, and will certainly leave if they find more opportunity in other nations.

I therefore respectfully request that regulations for accessories to Infrared Cameras and Detectors be relaxed. Working with the established international infrared camera companies in allied nations will improve our business, create more revenue, and create more jobs. I hope you will consider the impact of these ITAR changes will have on some very good small businesses.

Princeton
Infrared Technologies

June 23, 2015

Via email DDTCResponseTeam@state.gov
Publiccomments@bis.doc.gov

Re: ITAR Amendment - Category XII; RIN 1400–AD32; Comments on Notice of Proposed Rule Making.

ATTN: Mr. Ed Peartree, Director, Office of Defense Trade Controls Policy

Dear Sir,

Princeton Infrared Technologies, Inc. ("Princeton IR") submits the following comments on the proposed rule changes to the U.S. Munitions List, Category XII for your consideration.

Background

Princeton IR was founded in December 2013 to develop and manufacture infrared detector solutions, particularly one-dimensional indium gallium arsenide ("InGaAs") focal plane arrays, for various commercial applications. Commercial applications of Princeton IR's products include spectroscopy for material inspection, machine vision in factories for glass inspection, and monitoring dense wavelength division multiplexing telecommunication networks.

Overview

Princeton IR believes the proposed regulations would have a significant negative impact on the industry in the U.S. by promoting sales from international competitors. The increase in foreign sales would enable the international companies to invest in and develop new products, as well as manufacturing efficiencies that would ultimately lead to a decline in the technological progress at home. This would have potentially catastrophic consequences for the domestic industry, similar to those suffered by the U.S. satellite industry with the transition of satellite controls from the Commerce Department to the State Department.

The destruction of the domestic IR industry would have negative economic and national security consequences. Foreign competition would likely leap-frog over domestic production both in quality and cost, making better, cheaper product available outside the U.S. and increasing costs for U.S. defense contractors.

These costs would come with little to no benefit to U.S. national security to offset the costs. The types of products on which the proposed regulations tighten controls are already available from foreign competitors. Therefore, the proposed restrictions would not prevent parties outside the U.S. from obtaining these products. They would simply push those buyers to non-U.S. manufacturers, strengthening foreign competition and removing U.S. visibility into sales of IR products – visibility that the U.S. Government would have if the products in question were subject to the jurisdiction (and licensing requirements) of the Export Administration Regulations where many of these products currently reside.

For these reasons, discussed in further detail below, we respectfully submit that the proposed rules are counter to the intended goals of Export Control Reform to place higher walls around fewer items and to strengthen U.S. industries that support our national security with items that warrant export control but which are not appropriately treated as "defense articles." For these reasons, we strenuously object to the proposed rule changes in their current form and ask that the agencies involved submit modified proposals as soon as possible.

Discussion

This response will focus on shortwave infrared detectors (900nm to 2600nm) which the proposed rule would place under Category XII(c) of the USML - Infrared Focal Plane Arrays (IRFPAs). The IRFPAs discussed are detectors that are currently not purchased by the U.S. military, available overseas and many of them have historically only been subject to EAR99 regulations.

Princeton IR believes the rules as proposed are overbroad and could potentially cover commercial telecommunications and fiber optics devices wholly unrelated to the purpose of the USML restrictions. Princeton IR also believes that, instead of placing more items in the wavelength band under the USML control, the revisions should be focused on building higher walls around fewer products. This comment will outline the disadvantages of the proposed rule and suggest alternatives, when applicable, to address these concerns.

1. Proposed Paragraph (c)(2) - IRFPAs

The proposed paragraph XII(c)(2) would bring photon detectors in the range of 900-30000 nm, not integrated in a permanent encapsulated sensor assembly, onto the USML. The proposed regulation does not even restrict the regulation to photon detectors attached to an amplifier. As a result, every fiber optic telecommunication receiver currently in production would be placed on the USML subject to the ITAR.

For example, InGaAs p-i-n and APD (avalanche photodiodes), which can be packaged or unpackaged in TO cans, would both qualify under the "permanently encapsulated sensor

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assemblies" category. These photon detectors are readily available from manufacturers in China, but similar products would be governed by the ITAR under the proposed USML once they are brought into the United States.

The following table contains a few examples of devices that are readily available now, but which would be covered by the proposed rule:

Device Name	URL
InGaAs PIN Photodiode with Large Photosensitive Area Chip-on-Carrier	http://welcome.gofoton.com/product/ingaas-pin-photodiode-with-large-photosensitive-area-chip-on-carrier/
High Speed InGaAs Photodiodes	http://www.gpd-ir.com/high_speed.html
Simple InGaAs photodiode array without packages	http://www.alibaba.com/product-detail/Optoelectronic-chip-integrated-circuits-ingaas-pin_1783007100.html?s=p
Short 4x1 array on InGaAs photon detectors that can be repeated many times to form a 3x4 array for fiber ribbons	http://www.albisopto.com/albis_product/pdcaxx-32-sc/
12-channel optical receiver used in Datacom and telecom	http://www.avagotech.com/pages/en/fiber_optics/parallel_optics/12-channel_parallel_optics/afbr-83pdz/
45 element arrays of receivers	http://www.a3pics.com/a_spec.htm

Furthermore, the proposed definition of "permanent encapsulated sensor assembl[ies]" would encompass Short Wave Infrared ("SWIR") sensors. SWIR sensors are made from InGaAs and are able to withstand a wide range of temperatures, from -120° to 80°C. Sensor Unlimited's (United Technologies) 256, 512 and 1024 element linear arrays have been shown to operate at temperatures as high as 80°C with 80% humidity meeting Telcordia specifications. These devices are used to monitor dense wavelength division multiplexing ("DWDM") in fiber optic telecommunication systems across the world.

SWIR sensors that are not hermetically sealed provide a beneficial low-cost option to system manufacturers. Without the packaging, system manufacturers are able to integrate optics as close to the sensors are possible. Some applications of non-sealed SWIR sensors include field portable spectroscopy, hand held Raman systems, optical coherence tomography (medical imaging) and scientific spectroscopy. Sometimes, the sensors are placed in hermitically sealed enclosures to protect the device from dust, fingerprints, ESD, or to enable the device to work with thermoelectric coolers. Even when the devices are sealed, the seals currently in use can easily be removed without effecting the sensors' operation. These sensors are able to work as easily in a vacuum or in nitrogen as in the open air.

Based on the currently proposed language, the proposed regulation would require sensors to "self-destruct" when the seals are opened. Not only is this requirement challenging from an engineering perspective, it would also be cost-prohibitive to design such a device. Self-destruction also fundamentally defeats the SWIR sensors' unique advantage of operating without hermetic seals. Working without seals enables these sensors to be smaller, use less power, and cost less than HgCdTe, Ge, or InSb sensors.

In short, the proposed regulation would unnecessarily regulate these commercially available and commercially used sensors, causing a significant increase in the cost of these devices in the U.S. As a result, companies would turn to foreign providers, ultimately hindering progress in the development and improvement of technology at home.

2. **Proposed Paragraph (c)(3) – One-Dimensional Photon Detector IRFPAs**

Princeton IR is unaware of any military system, anywhere in the world, that uses a one-dimensional photodetector array in the SWIR band (900-2600nm). Thus, Princeton IR believes that this proposed paragraph should be removed in its entirety and linear arrays should continue to be controlled as EAR99. Further, we believe that the distinction between square pixels and tall pixels should also be removed from the CCL list, such that SWIR products using tall or square pixels should fall within the EAR99 classification.

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First, it is important to note that many telecommunication detectors are manufactured in arrays called linear focal plane arrays fall under this section. Since these arrays are never packaged, the detectors would be subject to significantly heightened controls, with no national security benefit. The array sizes of 1024 elements and 2048 elements are currently available from foreign suppliers and have been sold for years in the U.S. and around the world.

The following table contains a few examples of companies that sell these types of arrays:

Device Name	URL
12 channel 10Gb/s detector array (Singapore)	http://www.avagotech.com/pages/en/fiber_optics/parallel_optics/12-channel_parallel_optics/afbr-83pdz/
4x1 array (Switzerland)	http://www.albisopto.com/albis_product/pdcaxx-32-sc/
256x1, 512x 1, 1024x1 and 2048x1 on pitches from 50um to 10um (USA)	http://www.sensorsinc.com/products/detail/le-series http://www.sensorsinc.com/products/detail/gl2048-r-ingaas-linescan-camera
512x1, 1024x1 and 2048x1 (Belgium)	http://www.sinfrared.com/en/infrared_camera/detector_arrays_for_infrared_linescan_imaging_and_spectroscopy_applications/xlin_detector_series.asp
Camera systems using the arrays (Belgium)	http://www.sinfrared.com/en/infrared_camera/swir_-_short_wave_infrared_cameras/lynx-gige_-_high_resolution_high_speed_uncooled_swir_gige_line-scan_camera.asp
1024 on 25um pitch (Japan)	http://www.hamamatsu.com/us/en/product/category/3100/4005/4208/4121/G10768-1024DB/index.html
256 element arrays (China)	http://en.cnki.com.cn/Article_en/CJFDTOTAL-JGHW200611007.htm http://www.medsci.cn/sci/show_paper.asp?id=2608159269

The examples above are only used in commercial applications.[1]

Second, we believe that most of the linear array sensors in this band were developed using private funding. Based on our research, we believe that there has been no U.S. Government funding of linear arrays in this wavelength band in **over 15 years**. With no Defense Department financial interest in the technology, it is highly unlikely that the U.S. military is currently deploying, or is interested in deploying, a one-dimensional array in the future. These are commercial technologies.

[1] There are systems that are TDI (time domain integration), but TDI systems are made by adding multiple linear array elements together, which differentiates them from pure one-dimensional arrays.

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Requiring arrays to be less than 640 elements appears to be unnecessarily restrictive. As discussed above, 1024 elements and 2048 elements are currently available worldwide and, in the U.S., the linear arrays are classified as EAR99 with tall pixels. The detectors are listed on the Wassenaar dual-use list as 6(A)(2)(a)(3)(d)(2). In both regulations, the number of pixels has never mattered. Thus, the new requirement would greatly increase the number of licenses by essentially requiring many DWDM monitors to have a license.

An ITAR licensing requirement would create a significant disadvantage to U.S. producers, again with no gain in national security, because it would prohibit some sales and would create delays in deploying new fiber optic systems. Licenses would be required by every manufacturer and purchaser of DWDM. Companies that design DWDM systems generally ship in the range of 1,000 - 10,000 at a time, all of which would require licenses for each device. Optical Coherence Tomography is in development using InGaAs linear arrays of 1024 and 2048 elements. These systems will be deployed to doctor's offices and hospitals on the order of 1000s. Furthermore, any doctor's offices or university laboratories that use the technology would need to obtain a number of licenses for their systems. These licensing requirements are both burdensome and unnecessary in this field.

Third, these controls are unnecessary, because turning commercial linear arrays into a military night vision system with scanning mirrors is not even technically feasible. A true one-dimensional array (not TDI) would not be capable of night vision imaging or laser spotting for several reasons:

1. The scan rate to create a 2D image would be too limited making it difficult to image at night.
2. The scan rate for high resolution would be too low for mobility.
3. A scanning system would have a limited frame rate. Thus, imaging a short pulse laser would be close to impossible to do on a regular basis. Many military systems require a snapshot exposure—not a rolling mode exposure—because otherwise one would miss the laser pulses. In comparison to rolling mode exposure, line arrays are even slower.
4. It is difficult to build a traditional 2D imaging system with these arrays. The only way to create a 2D image is to integrate a scanning mirror. To do so, one must run the array quickly while the mirror scans the linear array across the scene. Alternatively, the array must be placed on a satellite or moving platform which creates a scan underneath the array.

To illustrate the complications of using linear arrays in night vision applications, we will describe the process using the Xenics linear array from above. The Xenics array can output 10klines/s at 2048 resolution. If one wanted a 2048x2048 image from the array, then one could only make video at <5 Hz due to the line rate. This line rate is too slow for any

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military application, 9Hz cameras are already on the Wassenaar dual use list. Integration times for any given pixel would be 97us which is also too small for night vision imaging. Two-dimensional arrays in this wavelength band for night vision integrate for 16-33ms which is >160x longer than the Xenics 1D scanning system. The 2D imager requires the 33ms for ¼ moon imaging with a 15x15um pixel at <35e- of noise. This linear array has a smaller pixel ratio, 12x12um, which means each linear array pixel captures 50% less light than the 2D imager. Altogether, the linear array pixel would capture 320x fewer photons per pixel than the 2D array. Therefore, this linear array scanning camera system would only be able to work in the daytime—assuming the array has 35e- of noise. The linear array actually has a 600e- **noise floor**. Even limiting the field of view and creating a 2048x1024 scene would only increase the frame rate to ~10Hz with the total signal to noise ratio of >5400x less than the current 2D imagers which only image to ¼ moon. As a result, these linear arrays could never be used as a night vision imager.

For another example, Sensors Unlimited's 1024 linear array on 25um pitch provides a higher line rate of 46klines/s. One could form a 1024x1024 image with a 44Hz frame rate with each pixel having an integration time of 20us. While we would have a faster frame rate, the cost would be 1000x less integration time from what a 2D imager could achieve (33ms integration times). Even cutting the frame rate to 10Hz only gives an increase of a factor of 4 in integration time. With this integration time, the system would not even be able to work at dusk let along night. Thus, the physics does not allow linear arrays in this wavelength band to be used as night vision devices. The scanning alone reduces the integration time too much. If the linear arrays had 1e- noise levels, the signal to noise ratio would be increased by a factor of 35, which is still not enough to allow the array to be used at night. This linear array has an SNR of 3200x less than an equivalent 1280x1024 array on 15um pitch which images at ¼ moon. This would make this system barely able to image at dusk let alone at night. This is the exact reason why almost every LWIR and MWIR cooled scanning thermal imager in the USML arsenal is being replaced by 2D arrays.

In addition, linear arrays cannot be used to create scanning systems to spot laser designators or rangefinders. To elaborate, we begin by assuming the scanning system is making a 2048x2048 image. If the laser is firing at 15Hz, the pulse would occur 3x during one frame of scanning with a 5Hz frame rate. The laser pulse would be <100ns in pulse duration and the integration time of each line would be 0.1ms. We can only image one line at time with a scanning system. During the frame time of 5Hz, the pulse occurs 3 times in the same spot (assuming a 16Hz laser). The line is only on 1/2048 of the frame time. Thus, in this scenario there is only a **0.15%** chance of catching the laser pulse. It would be nearly impossible to trace laser beams back to their source with this type of scanning system, in fact, most of the time; the system would not even see the pulse.

Even using a faster Sensors Unlimited array, the laser pulse would occur approximately once every three frames. Sensors Unlimited Array allows a 44Hz frame rate and the pulse rep rate is 15Hz. Since the short pulse is less than one line time, the chance of catching that line time is 1 in 1024 or **0.09%** and would only occur once every three frames. The system would not be effective in capturing laser pulses.

Thus, to use the arrays, one would need to design a sophisticated system with scanning mirrors, a stabilization platform and software to reassemble the information to produce the image. The stabilization platform would require significant resources and time to develop. It would actually be much simpler for users to get a high sensitivity visible silicon sensor with no coatings or coating optimized for 1.06um to spot lasers. These sensors are readily available worldwide at high or low resolution and are incredibly inexpensive:

- http://www.lumenera.com/resources/documents/datasheets/industrial/Lt225-datasheet.pdf
- http://www.lumenera.com/resources/documents/datasheets/microscopy/infinity3-3URF-datasheet.pdf

Finally, the differentiation between square linear array pixels and rectangular linear array pixels needs to be removed from the CCL. While tall pixels can be used to create 2D images, they are blurry. To sharpen the image, users may place an aperture in the optical system to transform taller rectangular pixels into square pixels. Placing an aperture would greatly increase the cost of the system but does not help in protecting any soldiers. Thus, this rule is forcing users to apply greater image processing to tall pixels by unnecessarily requiring apertures in their optical systems. It is much easier to instead buy square pixel systems from overseas. As a result, the differentiation does not add anything to the regulation and should be removed.

Also, one-dimensional arrays are categorized based on the number of pixels (640 pixels) and detection range >900nm and <30,000nm. This is an inappropriate and seemingly random specification, and the proposed regulation does not indicate why these ranges would have a military application—especially since one-dimensional arrays in the range of 900-1700nm are not currently used in any deployed military systems. Many of the linear arrays also have prior Commodity Jurisdiction determinations that classify them as EAR99. Globally, these products are on the Wassenaar dual-use list. These linear arrays and linescan cameras have been used in semiconductor inspection, glass inspection, spectroscopy, and many other machine vision applications. The proposed changes would fundamentally change the business by forcing builders of these systems to use foreign made InGaAs linear arrays, negatively impacting U.S. companies.

Princeton IR has also been developing readout integrated circuits (“ROIC”) from private funding. ROICs are not built for military applications, but, due to the proposed changes, the ROICs would be subject to the USML. ROICs have no military significance, as they cannot be used as for night vision devices and are too slow to image laser designators.

For the above reasons, we believe the proposed regulations are overbroad and should either be amended or discarded in their entirety.

3. Proposed Rule on Two-dimensional Arrays

Categorizing arrays as "two-dimensional" is not an appropriate way to distinguish between military and non-military applications in the USML and CCL.

The parameters chosen do not set bright lines and are overbroad. The proposed regulation does not define night vision devices or military grade infrared imaging device. As long as the peak responsivity is in the range and has an ROIC, the device would be included on the USML and subject to the ITAR. The regulations, instead, should include parameters about amplifiers with row switches. Otherwise, ganged telecommunication devices would easily fall within this category.

Furthermore, the distinction between what is currently available worldwide and what is considered USML should be clarified. SWIR 2D imagers are rarely deployed in the United States military arsenal, and there are no plans for large orders in the near future. As a result, 2D imagers that are actually used in military deployed systems should be considered USML, but everything else should be on the CCL list.

3.1. Two-dimensional arrays in paragraph (c)(2), (c)(4)

We believe the language in proposed Category XII(c)(2) is overbroad and covers all permanently encapsulated sensor assemblies that detect in the range from >900nm to <30,000nm with our without amplifiers. For example, as noted above, any telecommunication detector element used in fiber optic telecommunications would fall under the regulations. Single element photon detectors are readily available now and have been deployed worldwide for years.

In addition, the language in proposed Category XII (c)(4) is too broad, because it includes all 2D detectors with >256 elements (or 16x16 focal plane arrays) that are packaged. Currently, there are very few 2D image sensors in this wavelength band that are actually deployed in military systems. The few deployed SWIR sensors are 640x512 or higher resolution, have very high sensitivity and low noise (>80% QE at 1.55um and noise floors <35e- for a given 12 to 25um pitch). They also have many features including large dynamic range that allow them to handle many light levels and they are hardened for military environments.

The scope of the proposed USML also needs to clarify how to distinguish between a military and nonmilitary sensor. One way to distinguish the categories would be to define a D* number or another measure of sensitivity adjusted for noise, response and pixel area. Other metrics could also include resolution and pixel pitch. The proposed regulation also does not define what an infrared focal plane array is and what it does.

Furthermore, and as discussed above, any two-dimensional detector array would be considered ITAR if it is not "permanently encapsulated." The disadvantages of calling out permanently encapsulated sensor assemblies are described in the previous section.

Regarding what is currently available worldwide, arrays as large at 640x512 are readily available from foreign sources. Last April, SCD in Israel announced that it is moving to 1280x1024 on 10um pitch for InGaAs in the SWIR band, 900nm-1700nm. The ROICs for 1280x1024 on 15um pitch in SWIR are also commercially available outside this country (i.e. Turkey). Thus, the restrictions would set the U.S. behind countries like Israel and Turkey.

The following list contains a few other examples from around the world:

- China- GHOPTO
  - 640x512 -25um pitch arrays - http://www.ghopto.com/en/index.php?m=content&c=index&a=show&catid=14&id=63
  - Cameras - http://www.ghopto.com/en/index.php?m=content&c=index&a=show&catid=14&id=63
- Taiwan- Chungwah
  - 640x512-25um pitch - http://www.leadinglight.com.tw/images/Small%20format%20FPA%20spec.pdf
- Japan- Hamamatsu
  - 640x512-20um pitch cameras
    - http://www.hamamatsu.com/resources/pdf/sys/SCAS0074E_C10633-34.pdf
  - 128x128 on 20um and 50um pitch sensors
    - http://www.hamamatsu.com/us/en/product/category/3100/4005/4208/4125/G12242-0707W/index.html
    - http://www.hamamatsu.com/us/en/product/category/3100/4005/4208/4125/G12460-0606S/index.html
- France- Sofradir
  - 640x512-25um pitch InGaAs
    - http://www.sofradir.com/product/snake-sw/

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        - 1000x256-30um MCT (0.4-2.5um)
            - http://www.sofradir.com/product/saturn-visir-2/
- France- New Imaging Technologies
    - 640x480-15um pitch InGaAs
        - http://www.new-imaging-technologies.com/ingaas-products.html
- Belgium- Xenics
    - 640x512-20um pitch InGaAs (0.9-1.7um)
- Israel- SCD, Inc.
    - 640x512-15um pitch InGaAs
        - http://www.scd.co.il/SCD/Templates/showpage.asp?DBID=1&LNGID=1&TMID=108&FID=1287&IID=1682
    - 1280x1024-10um pitch InGaAS
        - http://www.scd.co.il/SCD/Templates/showpage.asp?DBID=1&LNGID=1&TMID=178&FID=1148&PID=0&IID=1780
- Turkey
    - 1280x1024-15um pitch ROIC for InGaAs
    - This ROIC is built for InGaAs and is commercially avaialable with rms noise of less than 5e-
        - http://www.mikro-tasarim.com.tr/products/view/3

Moreover, for night vision, the U.S. Military is only using a few SWIR focal plane arrays (<300/year) because they do not perform as well as night vision goggles. Regarding the ability to detect lasers of 1.06um, silicon cameras (similar to the cameras on cell phones) already exist to detect the signals at high resolution and with low noise imagers. Of course, camera phones are not restricted under the USML. These sensors are readily available worldwide at high or low resolution, are incredibly inexpensive, and are currently deployed in munitions and laser spotter systems:

- http://www.lumenera.com/resources/documents/datasheets/industrial/Lt225-datasheet.pdf
- http://www.lumenera.com/resources/documents/datasheets/microscopy/infinity3-3URF-datasheet.pdf

Instead, there are many commercial applications of these SWIR arrays including hyperspectral imaging, machine vision, laser beam profiling, semiconductor inspection, glass inspection, pulp and paper processing, art inspection, and thermal imaging. Since these designers are now looking for higher resolution and greater sensitivity, the companies would need to look to foreign SWIR imagers due to the proposed rule.

3.2. Proposed Category XII(v)

This proposed section states that "specially designed" camera cores with 1D and 2D arrays would be subject to the ITAR if the array has more than 640 elements. However, the majority of linescan cameras (1D) were designed with private commercial funding and none are used in military systems at this wavelength range. The proposed regulation would therefore restrict almost all spectrometers on the market in this wavelength range. It is unclear how the camera electronics and 1D arrays greater than 640 elements are military grade, especially when there are thousands of these devices in telecommunications networks across the world. These devices are currently classified as EAR99, and this is where they should remain. After all, and as discussed above, the 1D arrays cannot be used in night vision devices or laser spotting systems. In addition most spectrometers in the world use linear arrays and electronics to run the 1D imagers. This would put almost every spectrometer in the ITAR category.

3.3. Proposed Category XI(vii)

Proposed Category XII(vii) is similar to (v) but adds the "permanently encapsulated sensors assembly" language. Essentially, this proposed provision states that camera electronics at any resolution would be subject to ITAR. Again, the proposed regulation is overbroad and would apply to the millions of telecommunication receiver arrays and spectrometers installed today. These devices are not currently being used in any military systems, were not designed for military systems, and many linear array cameras are available worldwide with higher resolutions and frame rates. These devices are sufficiently regulated under the EAR as EAR99, and no changes should be made to the process. Furthermore, section XII(v) already encompasses the majority of the requirements under XII(vii) and it is unclear why a separate classification is needed.

3.4. Proposed Category XII(viii)

This proposed classification covers camera modules in the wavelength range of 900-2500nm with less than 111,000 elements. Again, the restriction is overbroad especially in reference to the devices currently available in the market. An 111,000 element array is slightly larger than a 320x256 imager. Using the number of elements as a restriction does not provide an appropriate bright line to categorize camera modules. As stated earlier, the regulation should restrict camera modules "specially designed" for military systems. General camera modules with SWIR response should not be covered since they are not night vision devices and are not made to spot lasers. The USML should be focused on exporting hardware which could compromise our technological advantage. As a result, it would be better to restrict camera modules that were specially designed for a military system and describing those metrics more specifically. Again, these metrics include sensitivity, resolution, frame rate, and pixel pitch specifications for a given size, weight and power that makes this a military system.

Currently, the proposed regulation just serves to limit the currently available commercial devices that the U.S. military would never even purchase. As stated earlier, the Department of Defense has deployed very few systems with imagers across this wavelength range, because the current sensitivity at room temperature is not good enough for night vision imaging. Increasing the size, weight, and power would allow for greater night vision, but the system would become too large or require too much power to be deployed by an enemy. As such, Princeton IR believes that the regulations should be rewritten to better distinguish between military and commercial devices.

3.5. Proposed Category XII(e)(3)

This section discusses wafers incorporating structures for either a ROIC (paragraph (e)(4) or (5)), an IRFPA or detector elements (paragraph (c)(2)). Princeton IR again believes this regulation is overbroad and should be removed.

A basic interpretation of the proposed classification means that it covers any component of the formation of the IRFPA. As a result, manufacturers of telecommunication detectors and IRFPAs would need to obtain ITAR licenses for the entire SWIR formation process. These devices are manufactured using a mask set, and that mask is repeated across a wafer creating an array of detectors. Even a single element device is a detector array at the wafer level thus placing the wafer as ITAR USML. Since most of the substrate materials are manufactured and growth of the material currently occurs outside the United States, every telecommunication detector manufacturer would need to obtain ITAR technical data licenses to allow them to share product specifications and requirements necessary to obtain the material for production in addition to their current procurement processes. Some companies even diffuse their wafers in reactors outside the United States, which would also require licenses. Adding restrictions to an already difficult to obtain material is undesirable—three ITAR authorizations may be needed just to cover the process. The new proposed regulation would overburden the process and take away from the U.S. advantage of combining of the detector material with the ROICs. Commercial products and R&D in Universities as well as labs would all need licenses just to obtain raw material. The key element is the final device not the various parts that compose it. Since there are few manufacturers in the U.S. the state department is creating unnecessary hurdles for material readily and mostly available outside the U.S.

As a result, the restrictions need to be clearer regarding whether the above licensing situation is necessary. As it stands, the regulation does not protect American interests, because it simply forces U.S. companies to obtain too many licenses, whereas the technology is already more readily available in other countries. This does not fit the definition of higher walls around fewer items.

3.6. Proposed Categories XII(e)(4)(i) and (ii)

This section covers ROICs designed for: (i) One-dimensional photon detector IRFPA having greater than 640 detector elements; (ii) Two-dimensional photon detector IRFPA having greater than 256 detector elements. As discussed in a previous section, the Department of Defense has not invested in a 1D linear array in over 15 years with a wavelength in the range of 700nm to 2500nm. The Department of Defense also has not deployed linear arrays in any system in over 15 years and there are, to the best of our knowledge, no plans to deploy a 1D array across this wavelength band. As a result, it does not make sense to place a restriction on IRFPAs with over 640 elements.

Even if the regulation is enacted as proposed, the linear array ROICs are currently available from Japan, France and Belgium. Thus, the max of 640 elements seems to be an arbitrary number. As discussed earlier, there are no military applications of one-dimensional photon detector IRFPAs and, as such, these ROICs should not be included on the USML. On (ii) for two dimensional arrays, the regulation should clarify the requirements in terms of frame rate, read noise, amplification and pixel pitch or simply include items that are “specially designed” for military applications. Restricting the number of pixels does not clearly separate military and commercial applications, have any military significance, or show how without the regulation it would be detrimental to national security. The regulation merely protects the enemy by placing costly burdens on U.S. manufacturers and by making it more difficult to sell our product as compared to the rest of the world. The more ROICs sold by foreign companies, the smarter they become in manufacturing and design, and over time, the U.S.’s technological advantage will be lost. The restriction on ROICs need to be for military articles only. A definition of a military ROIC needs to be established.

3.7. Proposed Category XII(e)(9)

The proposed regulation in this section on lenses that relate to IR imagers is too restrictive. We interpret the proposed regulation to mean that all optical elements that work with imagers, even for commercial applications, would be restricted by the ITAR. The regulation should instead only cover optical elements specifically designed for military systems. There is no reason why commercial lenses with coating for this wavelength band or materials optimized for this wavelength should be restricted under the ITAR.

4. Comments on other modifications of the CCL

4.1. General Commentary

The CCL is complicated, lengthy and should be simplified to better serve the needs of small businesses. Currently, we are able to manage the workload with minimal advice from our attorneys. However, due to the new, complex language and overuse of acronyms, small businesses must hire expensive attorneys for advice and assistance in establishing the correct procedures for exports. Businesses also need to pay for a full-time administrator to handle the increase in paperwork and documentation. The modifications were meant to simplify the process, but we believe the changes have actually made the process more difficult.

4.2. Additions to Section 740.2

First, the metrics used in the regulations do not provide a sufficient basis for a night vision imager. As stated above, the linear arrays are incapable of imaging at night, even under full moon conditions, because of their limited integration time and scanning needs. The 2D imagers also cannot image at night unless they have very low noise performance or large pixels—neither of which is noted in the USML or CCL guidelines. The regulations should be amended to include performance metrics that more accurately characterize night vision cameras beyond the number of pixels. Furthermore, the one-dimensional imagers in the SWIR range of 0.9-2.5um have never been used as a night vision device and have never been deployed in military systems. The 2D SWIR imagers have been deployed in very limited unumbers but had very specific performance specifications that were adjusted for the military application and contained specialized firmware for use in the field.

4.3. Addition of Definition to Part 772

As discussed previously, "permanent encapsulated sensors assembly," is not the best way to categorize the sensors. The primary advantage of InGaAs SWIR sensors is their ability to operate without a hermetically sealed packaging and without cooling. As mentioned, this rule would hinder U.S. manufacturers' ability to compete in the world market for commercial product. The alternative would be to build a package that deactivates the device upon opening, but this solution is technically challenging and very expensive. We reiterate that the concept of "permanent encapsulated sensors assembl[ies]" should be removed in its entirety from all regulations.

4.4. Revisions to ECCN 0A919

We believe this section states that parts that meet 6A002 or 6A003 are controlled if one imports them from another country even if there are no U.S. parts on board. The regulation would create a flood of unnecessary license requests and should be amended to simplify the process.

4.5. Revisions to ECCN 6A002

ECCN's RS controls would require licenses for all destinations, including Canada, for the entire entry. This appears to be unnecessary for linear arrays which are not night vision capable and not capable of being used to image lasers in the two-dimensional format as stated above. Also, as discussed above, there are commercial alternatives available worldwide.

The proposed rule would also supersede the linear arrays with tall pixels which are already subject to the less-restrictive Wassanaar list. Without clearer specifications focused on night vision cameras, two-dimensional arrays would be subjected to tougher licensing standards. There are many commercial applications for SWIR imagers not in permanent encapsulated sensors, so the proposed rule would cause a tidal wave of license requests. (As discussed previously, these linear arrays are used in spectrometers in university labs and companies all over the country and would burden a significant population to obtain the appropriate licenses.)

4.6. 6a990

We understand the DoD is trying to restrict sensitive information on military grade ROICs from leaving the country; however, to be effective, the regulation needs to distinguish military and commercially designed ROICs more clearly. Commercial ROICs should be excused from the CCL and USML by drafting regulations with more specific characteristics such as frame rate, read noise and dynamic range. Even if the ROICs are restricted in this country, IRFPA ROICs are readily available worldwide up to resolutions of 1280x1024. Furthermore, linear arrays were almost all developed using private funds and were never created with a military application in mind. The technology also does not easily allow for night vision imaging and is not capable of imaging a laser spot.

Note: We believe that the exception for ROICs valued under $500 appears reasonable Wafers from a foundry cost about $5,000, and one receives more than 10 chips even for larger devices.

4.7. Revisions to ECCNs 6E001 and 6E002

The proposed rule puts harsh restrictions on the commodities related to manufacturing a focal plane array including substrates, epitaxial grown materials, zinc diffusion, software and firmware in cameras. The commodities portion of the proposed rules is our biggest concern because lattice matched InGaAs epitaxial wafers are currently not made in the United States. Due to the commodities restriction, the proposed rule would require all companies to get a license. We believe the rule will heavily impact the SWIR and

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telecommunications industries unless and until licenses are issued. (Companies that manufacture telecommunications devices use InGaAs detector material for single element devices and would be subject to the same regulations.)

A license would also be required for the software that interfaces with the arrays for either manufacture or testing applications including the software that interfaces with the cameras. U.S. companies using non-U.S. workers—including consultants, visitors, or temporary employees—would be subjected to the heightened regulations even if the cameras are just in the U.S. plants. Any person in the company with access to the cameras would place the entire company in violation of the proposed rule.

As a result, this rule is not protecting U.S. technology and is just making SWIR commercial equipment more difficult to use. Companies will resort to other solutions ultimately weakening the SWIR industry at home.

5. Conclusion

For the foregoing reasons, the proposed regulations are generally overbroad than the current rules and pull many items from the EAR99 to the USML list. Princeton IR believes more bright lines are necessary to distinguish military hardware from commercial hardware. Furthermore, Princeton IR believes that more investigation should be conducted to understand the technology readily available worldwide. The far-reaching implications of the proposed regulations would have serious impacts on a number of industries.

Respectfully submitted,

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July 2, 2015

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To:
Office of Defense Trade Controls Policy
Department of State
Washington D.C

Re: Proposed amendment to the International Traffic in Arms Regulations (ITAR): Revision of U.S. Munitions List Category XII (RIN 1400–AD32)

Dear Sir/Madam,

Princeton Instruments is providing the following comments towards the proposed revision to Category XII published on May 4, 2015 as part of Export Control Reform (ECR). Specifically, Princeton Instruments would like to comment on Paragraphs (c)(1) to (c)(9) which pertain to certain image intensifier tubes, infrared focal plane arrays (IRFPAs) and charge multiplication focal plane arrays and associated cameras under ITAR.

Summary Comments

Princeton Instruments believes that the proposed revisions to Category XII published on May 4, 2015 as part of Export Control Reform (ECR), constitute a technology dragnet that will be rife with unintended negative consequence and strategic damage to the United States. It will be tantamount to scientific book burning in its effects on the U.S. industrial base and on university research. And ultimately, it will have an opposite effect to what is intended on foreign availability.

The proposed revisions would so constrict the U. S. market for scientific cameras (and collaterally, spectrographs that employ cameras as detectors) at universities and commercial enterprises that domestic development and manufacture of ICCD's, EMCCD's and InGaAs scientific cameras will vanish from the U. S. Development of these products will be consolidated in Europe and Asia where most of the sensors employed in these products already originate.

Princeton Instruments produces ICCD, EMCCD and InGaAs cameras which are used by our national laboratories and in universities performing cutting edge physical science and medical research.

Every single foreign sale of these products by Princeton Instruments is already export controlled and many pending sales are denied. This affords the U.S. Government cognizance, oversight and control of the deployment of these products around the world. The proposed category XII revisions would so limit our sales of these products to even US universities with significant numbers of foreign affiliated researchers so as to make the business not viable. On the other

hand, our European and Asian competitors will freely benefit. A significant national resource will be destroyed. And, Government cognizance, oversight and control will be forfeited.

Uncontrolled foreign manufacturers of these products will be substantially strengthened by the proposed revisions. They will aggressively market these products with "ITAR free" slogans to ensure unfettered supply to end users.

University research performed with the impacted scientific ICCD, EMCCD and InGaAs cameras and spectrographs will migrate to foreign institutions because the use of even foreign-produced equipment will be impractical because of ITAR restrictions.

We strongly urge reconsideration and reformulation of the proposed Category XII revisions.

Detailed Comments

Princeton Instruments designs and manufactures scientific charge coupled device (CCD), intensified CCD (ICCD), electron multiplication CCD (EMCCD), x-ray and InGaAs sensor based cameras, spectrographs, optics and coatings. We are located in Trenton, NJ and Acton, MA and employ scientists, engineers, technicians and skilled labor who perform product development and system integration and test. Our products contain approximately 75% content from American suppliers. For over 35 years, we are the leading supplier of scientific cameras for medical and physical science research. Thousands of scientific papers are published in leading academic journals and many important scientific breakthroughs have been made with Princeton Instruments cameras and spectrometers (see EXHIBIT A).

- More than 55% of the camera products from Princeton Instruments are currently controlled by Commerce Control List (CCL) as "Dual Use" items under 6A003 and 6A203 categories.
- Over 70% of Princeton Instruments revenue is from exports.
- It is noteworthy that ALL of the "controlled" sensor technologies incorporated into Princeton Instruments products are from "**non-US**" suppliers. For example,
  - Image Intensifiers are imported from Japan and Holland.
  - EMCCDs are imported from UK.
  - InGaAs IRFPAs are imported from Belgium.
- None of the products are designed or enhanced specifically for military and are *not* ruggedized.

...continued

Princeton Instruments strongly opposes proposed Category XII amendments

The original intent of Export Control Reform was to build higher walls around fewer items which are exclusive to US ("crown jewels for national security and developed by US companies") and are of most military significance. However, the proposed amendments to Category XII, sections c(1) to c(9) which intend to bring ICCD, EMCCD and InGaAs sensor and camera technologies under ITAR control, while not in the spirit of the original intent, will actually lead to severe negative consequences.

Princeton Instruments strongly opposes these amendments because:

- **Foreign availability is not adequately considered.**
    - As shown in EXHIBIT (b), all these sensor technologies and cameras based on these sensors are freely available from EU and Asian companies.
    - They can be exported within EU without any export controls.
    - Already, most of these sensors and cameras are made available to foreign customers - EXHIBIT (c) that provide no oversight capability to US Government.
    - Even under the current EAR/CCL export regulations, US companies such as Princeton Instruments have to deal on a "non-level" playing field. Numerous examples exist where the foreign customer was able to obtain similar or better product after having been denied export license by US Government, a case is shown in EXHIBIT (d).

- **Discrepancy of controls between US and rest of Wassenaar countries**
    - Should the proposed amendments be implemented and ICCD, EMCCD and InGaAs cameras technologies are deemed USML/ITAR controlled, a significant discrepancy would arise between how US and its Wassenaar counterparts control these technologies.
    - While US would impose strict controls under ITAR, no such controls exist in EU countries. In fact, several of our EU and Japanese competitors would benefit as new controls will make US suppler less competitive.
    - Non-US companies with similar products will continue selling freely, and often promote their products using the words "ITAR-Free".

- **ITAR controls are burdensome even to US universities and research customers**
    - ITAR controls not only hinder sales to foreign customers, they adversely affect domestic customers as well
    - Many of our university customers indicated that they would not be interested in purchasing "ITAR" controlled products, as they would place undue burden on their laboratories and universities to safeguard and limit access to foreign students and affiliates. As many of the research labs employ foreign graduate and post graduate students, it will seriously impact research.
    - The status of hundreds of ICCD, EMCCD and InGaAs cameras shipped to US laboratories would significantly impact University's ability to control them.

- **Encourages US and Non-US customers to "design out" ITAR products**
    - All of these technologies are freely available outside US and the foreign producers will actively promote their "Non-ITAR" products which forces customers to move away from US ITAR products.
    - Many of these cameras are used in conjunction with "non-controlled" products such as spectrometers and CCD cameras, Princeton Instruments would see even higher revenue decline.

- **Disincentives for US companies like Princeton Instruments to invest in ITAR products and technologies**
  - Princeton Instruments estimates over 30% of its revenue will be lost if the proposed USML/ITAR amendments go through.
  - As a result, we will have to reduce workforce in Trenton, NJ and Acton, MA facilities.
  - As a virtual manufacturer with over 75% U. S. content, our American suppliers' employment would be impacted as well.
  - After over three decades of continuous innovation, it is a National tragedy to see significant engineering and manufacturing resources dwindle away while "Non-US" competitors continue to provide access to technology unimpeded. Stated goals for National security are not achieved.

Princeton Instruments recommends eliminating the proposed additions to Category XII C (1)-(9)

As these unprecedented and sweeping changes to bring ICCD, InGaAs and EMCCDs under ITAR controls are detrimental to US industrial and research base, we request that these proposals be fundamentally rewritten after sincere collaboration with stakeholders (industry, US Government, research universities).

Given the significant issues with the structure of the proposed rule, Princeton Instruments strongly suggests that either the US Government continues to use the existing Category XII language or if a second iteration of the proposed rule is requested that it replace "specifically designed" with "specially designed".

Sincerely,

William E. Asher
President
Princeton Instruments, Inc.

Exhibits:

a) A list of scientific research papers based on ICCD, EMCCD and InGaAs cameras
b) "Non-US" supplier list
c) Example of EMCCD exports to China
d) Example of an alternate supplier supplying similar ICCD and EMCCD cameras to a Chinese customer

EXHIBITS

a) List of scientific research publications based on intensified CCD (ICCD), Electron Multiplication CCD (EMCCD) and InGaAs sensor based cameras published in leading scientific journals

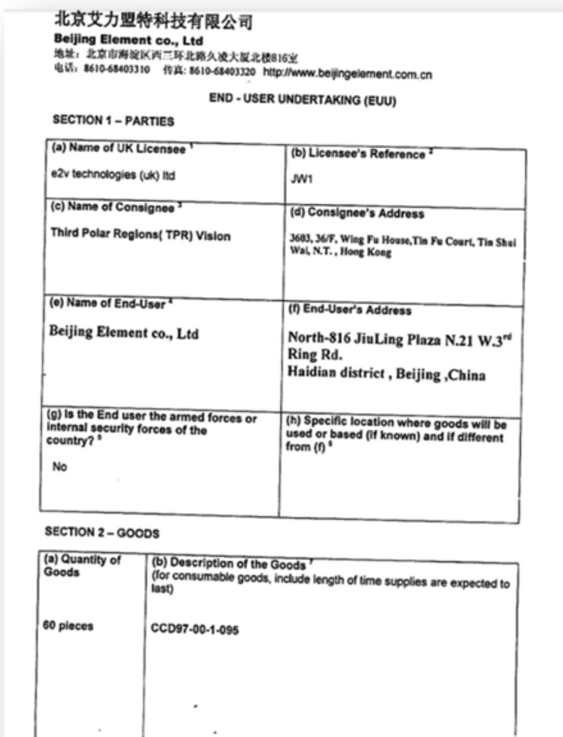
Controlled Technology	Number of scientific research publications (as of July 1, 2015). *Source: Google Scholar*
ICCD cameras	17,734
EMCCD cameras	9,722
InGaAs cameras	1,122

b) List of "Non-US" suppliers of ICCD, EMCCD and InGaAs sensors and cameras

	Controlled Technology	Non-US Supplier	Country of Origin	Website	Link to Product
1	EMCCD cameras	Chongqing Gangyu	China	http://www.camyu.net/	http://www.camyu.net/
2	EMCCD cameras, Intensified CCD cameras	Andor Technology (a division of Oxford Instruments),	Northern Ireland, UK	www.andor.com	EMCCD Camera ICCD camera
3	EMCCD and InGaAs cameras	Raptor Photonics	Northern Ireland	www.raptorphotonics.com	EMCCD Camera InGaAs Camera
4	Intensifier tubes, EMCCD and ICCD Cameras	Hamamatsu, Japan	Japan	www.hamamatsu.com	Intensifier Tubes EMCCD Camera ICCD Camera
5	Intensifier tubes	Photonis	Holland	www.photonis.com	Intensifier Tubes
6	Intensifier tubes, EMCCD and ICCD Cameras	Photek	UK	http://www.photek.com	Intensifier Tubes EMCCD Camera ICCD Camera
7	Infrared focal plane arrays and cameras	Xenics n.v.	Belgium	www.xenics.com	Cameras
8	Intensified CCD cameras, EMCCD cameras and InGaAs cameras	Photonic Science Ltd.	UK	http://www.photonic-science.com/	ICCD Camera EMCCD Camera InGaAs Camera
9	Infrared focal plane arrays	Chunghwa	Taiwan	http://www.leadinglight.com.tw/	Infrared FPA
10	Intensified CCD cameras	PCO	Germany	www.pco.de	ICCD Camera
11	Intensified CCD cameras	LaVision	Germany	http://www.lavision.de/en	ICCD Camera

12	InGaAs cameras	Allied Vision Technology (AVT)	Germany	http://www.alliedvision.com	InGaAs Camera
13	Infrared focal plane arrays, Intensified CCD camera and InGaAs camera	New Imaging Technologies (NIT)	France	http://www.new-imaging-technologies.com	ICCD Camera InGaAs Camera
14	EMCCD sensors	E2V Technologies	UK	www.e2v.com	EMCCD Sensors
15	EMCCD, InGaAs and MCT cameras	Photon etc.,	Canada	http://www.photonetc.com/en/	Infrared Camera EMCCD Camera
16	EMCCD and InGaAs cameras	First Light Imaging	France	http://www.firstlight.fr	EMCCD and InGaAs Camera
17	EMCCD camera	NuVu camera	Canada	http://www.nuvucameras.com	EMCCD Camera
18	InGaAs sensor and Camera	Sumitomo Electric	Japan	http://global-sei.com/products/compovision	InGaAs Camera
19	InGaAs camera	Artray	Japan	http://www.artray.co.jp	InGaAs Camera

c) Sixty (60) CCD97 EMCCD sensors exported to China from UK - License approval document from UK Government shown below.


北京艾力盟特科技有限公司
Beijing Element co., Ltd
地址：北京市海淀区西三环北路久凌大厦北楼816室
电话：8610-68403310 传真：8610-68403320 http://www.beijingelement.com.cn

END - USER UNDERTAKING (EUU)

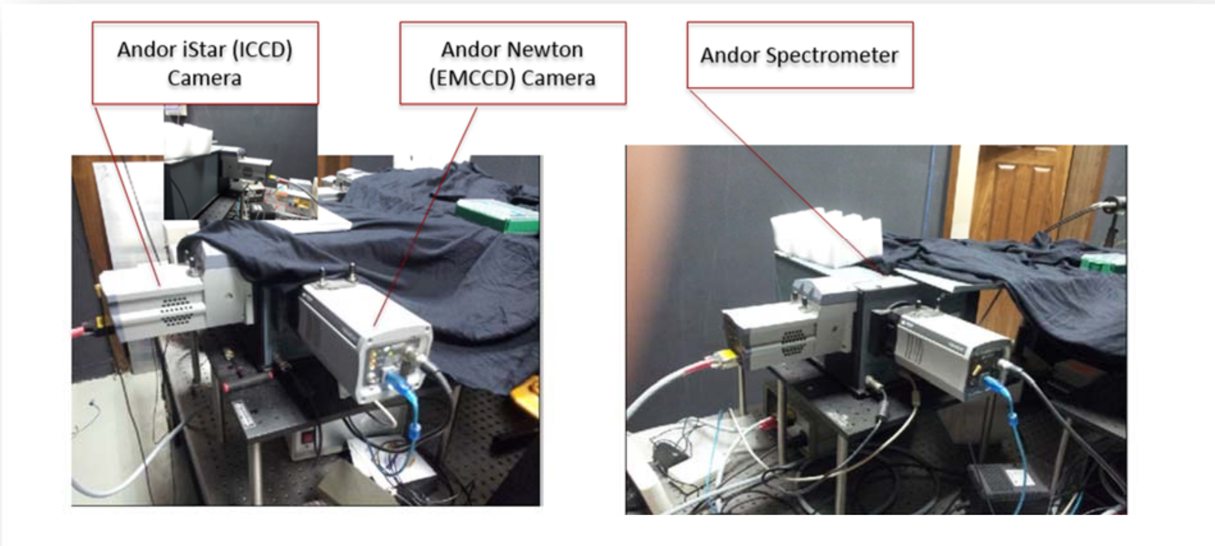
SECTION 1 – PARTIES

(a) Name of UK Licensee [1] e2v technologies (uk) ltd	(b) Licensee's Reference [2] JW1
(c) Name of Consignee [3] Third Polar Regions(TPR) Vision	(d) Consignee's Address 3603, 36/F, Wing Fu House, Tin Fu Court, Tin Shui Wai, N.T., Hong Koeg
(e) Name of End-User [4] Beijing Element co., Ltd	(f) End-User's Address North-816 JiuLing Plaza N.21 W.3rd Ring Rd. Haidian district , Beijing ,China
(g) Is the End user the armed forces or internal security forces of the country? [5] No	(h) Specific location where goods will be used or based (if known) and if different from (f) [6]

SECTION 2 – GOODS

(a) Quantity of Goods 60 pieces	(b) Description of the Goods [7] (for consumable goods, include length of time supplies are expected to last) CCD97-00-1-095

d) ICCD and EMCCD camera installations in China exported by Andor Technologies (UK). The purchase was made by the end user after denial by US Government.



Andor cameras and spectrograph installations at Shanghai Institute of Optics and Mechanics (SIOM, Prof. Jianjun Liu). No business from SIOM since 2013 E/L denials.

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To Whom It May Concern

Thank you for giving us the opportunity to comment on the proposed revisions of the Category 12 of the ITAR. Our company Chairman, Dr. Yves Dzialowski had sent in a separate letter with his comments on June 16, 2015. My letter focuses on specific areas of automobile LIDAR applications.

Princeton Lightwave is based in New Jersey. We have developed Geiger Mode Avalanche Photodiode (GmAPD) technology for the short wave infrared spectrum (SWIR wavelengths, 1-1.7 um). The technology is based on the Indium Gallium Arsenide (InGaAs) compound semi-conductor material system. We manufacture 3D imaging cameras based on this technology, and currently are the global market leaders in this product line for long range mapping and military applications.

The critical advantage of GmAPD technology is that they are sensitive to single photons, which provides for efficient short 3D imaging at short ranges, with minimal laser pulse energy. This, along with the SWIR operating wavelength ensures Class 1 eye safe operation for typical ranges required for situational awareness for automobiles.

In general, the SWIR wavelength spectrum is important for free space optics applications in public spaces, for example, optical wireless communications, range-finders, sensing and LIDAR, This is especially true for introducing safety and automated driving capability in automobiles, an area with growing interest due to its potential for reducing traffic accidents, enhancing efficient use of public infrastructure, providing mobility and independence to an aging population, and increasing productivity and comfort for a vast spectrum of daily commuters.

In the proposed revision of Cat XII, the note to paragraph (b)(6) allows focal plane array based LIDAR systems for automotive use at ranges less than 200m. Given the interest in automobile LIDAR, we believe this is a very good decision. However, based on our discussions with OEMs and Tier 1 suppliers, the 200 m range may be adequate for U.S. highways which mandate maximum speeds of about 100 km/hour. In other areas of the world (like parts of Europe) where maximum speeds approach 200 km/hour, the required range for LIDAR systems to enable safety features and support automated driving is 250-300m. Given the global nature of the automobile business, we are requesting that the amended regulations consider increasing the maximum range from the suggested 200m range to 300 m.

Additionally, Section (b)(8) (iii) places restrictions on use of Geiger Mode systems. Given the fact that a SWIR Geiger Mode LIDAR system can operate under Class 1 eye operation for the 200-300m ranges, we are requesting that Geiger Mode LIDAR systems

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in the SWIR wavelength be allowed for automobile applications for the range limits suggested above.

Princeton Lightwave's LIDAR technology can revolutionize the commercial autonomous driving market and lead to increased safety, reduced traffic fatalities, reduced traffic congestion and reduced pollution at a global level. It has dramatic consequences for our society for the next 3-4 decades. But unless we are able to work with OEMs and Tier 1s on a less restrictive export control environment, it is likely that other solutions outside the U.S. will be developed, that may be non-optimal and less effective, but the only way forward. Given the market opportunity, the bigger risk is that non-U.S. entities are motivated to develop the same capability as ours, which increases the proliferation risks, and causes a financial loss to U.S. industry.

Consequently, we urge you to consider our proposal above as the regulations are amended. It has dramatic consequences for our company, for American technology to lead in the automotive space once again, and for solving truly difficult global societal and infrastructural problems.

Thank you again, for the opportunity to contribute.

Sincerely,

Dr. Sabbir Rangwala
President and Chief Operating Officer
Princeton Lightwave
Cranbury, NJ 08512

www.princetonlightwave.com

From:	Yves Dzialowski
To:	DDTCPublicComments
Cc:	Yves Dzialowski
Subject:	ITAR Amendment - Category XII
Date:	Tuesday, June 16, 2015 11:30:54 AM

To whom it may concern,

Thank you for giving us the opportunity to comment on the proposed revision of the Category 12 of the ITAR.

At Princeton Lightwave Inc, in New Jersey, we manufacture Single-Photon Avalanche photodetectors for the short infrared, the spectrum between 1 and 1.7µm. Our devices are operating in Geiger mode. In this method, extremely small input light (as small as a few photons) triggers a measurable signal. In order to detect light in the above mentioned spectrum, we make our detectors with Indium Gallium Arsenide (InGaAs).
This spectrum is important to a fast growing and considerable commercial opportunity in the automobile industry. Lasers operating above 1.4µm are safe to the human eye and this enables mass deployment of optical sensors and LIDARs on public roadways.

In the proposed revision of Cat XII, the note to paragraph (b)(6) allows focal plane array based LIDARs for automotive use at less than 200m. However it is followed by paragraph (b)(8)which restricts systems that are designed using Geiger-mode focal plane array based detectors. In consequence, even for automobile use under 200m **(1)**, our devices are controlled by ITAR and it will be exceedingly difficult for us to sell in this market, effectively shutting us off from a market opportunity that will transform the auto industry, worth hundreds of Billions of Dollars.
Our request is to eliminate the carve out of Geiger mode cameras and LIDARs and treat them like other LIDARs under note (b)(6).
The 200m range limitation can be enforced in the design of the Focal Plane Array, and our cameras and LIDARs will have the same functionality than any other such LIDARs.
Our technology, of Geiger mode LIDARs and its components (cameras, Focal Plane Arrays) is, evidently, needed in Defense applications, we have been the beneficiary of funding by DARPA in particular and we are grateful for this support. Those applications are focused on long range LIDARs. Maintaining the ITAR restriction even for short range, in the auto industry, will affect our ability to compete, to improve and eventually to access markets where National Security is not, in our opinion, threatened.

Our cameras attract a high level interest in the automobile industry. The advantage our Geiger-mode technology offers compared to other methods for LIDARs in the automotive field is at least two folds:

1. it is eye-safe, it can be safely deployed on public roads and reach a adequate range for autonomy.
2. the Geiger-mode feature is more sensitive and allows to use a moderate power diode-laser as the LIDAR source to reach the same range. This is a simpler and scalable solution.
3. This combination of diode laser and Geiger mode detector makes possible an all-

semiconductor short range LIDAR, with the potential for low cost, a critical feature in a very competitive industry.

Today, besides working with US companies, we have initiated developments with leading suppliers in Europe, Japan and Korea. A couple have accepted to go through the license requirement, and we have been granted licenses. This is acceptable for development but will not be for production as they wish to market worldwide.
Another one has requested us to redesign with a single detector method in order to avoid ITAR; they do not want to introduce a product in the consumer market where supply could get interrupted on a decision of our government. This development, made in order to avoid ITAR, has limited performance and is uncertain to move forward.
Additionally, several potential users have unequivocally told us that they will not even start testing our products, as they do not want to invest time and resources if they cannot freely buy and sell. These include leading Tier 1 suppliers to the auto OEMS like Audi, BMW, Daimler, VW, Peugot and Renault, as well as U.S. OEMs.

This market is attracting foreign companies with capabilities similar to ours and of much larger size. Our cameras are based on this **InGaAs** material that has the advantage of operating in the eye-safe region. However single photon detection (Geiger mode) for proximity sensing and driver assistance is heavily funded by companies using **Silicon** detectors, operating at a shorter wavelength and good for shorter distances.

Toyota [2] of Japan, **STMicroelectronics**[3] of Switzerland, and **Samsung** of Korea, among others, have developed Avalanche diodes (SPAD) and focal plane arrays for single-photon detection. They use Silicon because some large volume applications are very short range (gesture recognition, proximity sensors for mobile phones), but their LIDAR/SPAD technology is a step away from ours and they will transfer to InGaAs in order to cover eye-safe wavelengths for auto.

Additionally, in China, companies like **Isurestar** [4], have already understood the value of eye-safe wavelengths and are offering InGaAs based LIDARs for automotive and other applications such as mapping. Baidu is partnering with BMW to offer driverless cars.
If we cannot easily export our cameras for this application, and extend the same freedom to our customers, there is no chance we can compete with such rivals. This would hold back a most promising American technology.
We have been able to obtain all the licenses that we have requested. So, except for the lost sales to customers who do not want to deal with the process, we have been able to maintain some presence. We estimate the lost opportunities have cost us time and revenues. Long term, however, the lost opportunity is extremely large as the automotive market will dwarf all others.

The prospect of autonomous driving and driver assistance is having every industry player extremely excited with LIDARs and their components (laser, camera, and processing software). Google, Uber, and legacy players are investing heavily in this space.
Consequently, we urge you to include our Geiger mode sensors in the LIDAR auto exception,

Thank you again, for the opportunity to contribute,
Respectfully yours,

Yves Dzialowski

Dr. Yves Dzialowski
Executive Chairman of the Board
Princeton Lightwave
+1 609 902 5743

Notes:

(1) We suggest that the distance should be increased to at least **300m**; this is the consistent message from the auto industry. The target for autonomy is to be able to detect a small obstacle on the road, at 300m, in good weather.

(2) http://redirect.state.sbu/?url=http://image-sensors-world.blogspot.com/2013/04/toyota-tof-imager-at-is-2013.html on Toyota's LIDAR for automotive

(3) http://redirect.state.sbu/?url=http://www.st.com/st-web-ui/static/active/en/resource/sales_and_marketing/promotional_material/flyer/flvl6180x0914_lr.pdf on ST Micro SPAD sensor for proximity detection and gesture recognition

(4) http://redirect.state.sbu/?url=http://www.isurestar.com/index.php?m=content&c=index&siteid=2 isurestar LIDAR website

Yves

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Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

1. [Introduction and Background Information]

Qioptiq Ltd (QUK) appreciates the opportunity to comment on the proposed changes to the USML.

QUK are a designer and manufacturer of electro-mechanical optical modules for defense and commercial applications. Its portfolio of products and technology includes Avionic head up displays and helmet mounted systems. Night vision (thermal and IR) for soldier/vehicle systems, target surveillance and acquisition systems. Space optics for satellites.
QUK supports many US programs under TAA/MLA; predominantly covered by Category XII. In addition QUK sources US licensed hardware, Image Intensifier (II) Tubes and IR Cameras for incorporation within its night vision products.

---

2. [Company size, location, and relevant product line]

Qioptiq Ltd
Glascoed Road
St Asaph
Denbighshire
LL17 OLL
UK

Currently employs approx. 500 employees

Relevant products lines -

Family of Weapon / Vehicle sights incorporating II Tubes and Thermal cameras FPA's.
Thermal and visible Optical modules in support of target surveillance and acquisition systems, missile warners.
Optical relays for Helmet mounted displays, Night vision goggles.
Parts, components and accessories with particular reference to Infrared lenses. Mirrors, beam splitters or combiners, filters, optical coatings.

3. [Direct comparison of non-military products with USML entries]

See below.

4. [Assessment of the appropriateness of the parameters and thresholds chosen to designate USML items.]

See below.

5. [Assessment of the overall scope of controls on the USML & CCL]

There are non US sources for both Image Intensifier and Tubes and Focal Plane Arrays that compete with the thresholds defined within the revised USML and CCL listing. These are offered for consideration when determining the appropriate controls for US technology and the impact they may have on the competitiveness of US manufacturers and suppliers.

Non US Sources are available for the following equipment:-

II Tubes
Gen III available from Harder Digital (Germany) with radiant sensitivity exceeding 20mA/W.
Gen II available from Harder digital with luminous sensitivity exceeding 500 microamps per lumen.
Photonis: http://www.photonis.com/en/#
Harder Digital: http://www.harderdigital.com/home/

Focal Plane Arrays
IRFPA's with a peak response exceeding 900 nm and less than 30,000 nm are available:- LWIR from ULIS (France), SCD (Israel); SWIR from SCD (Israel), Xenics (Belgium); MWIR from Selex (UK), AIM (Germany) and Sofradir (France)
In addition IRFPA's LWIR are available as 640x480 from ULIS, SCD plus others. XGA LWIR IRFPA are available from SCD (Israel).

ULIS: http://www.ulis-ir.com/index.php?infrared-detector=products
SCD:http://www.scd.co.il/Templates/showpage.asp?DBID=1&LNGID=1&TMID=86&FID=1208
Xenics: http://www.xenics.com/en
Sofradir: http://www.sofradir.com/products/

6. [Address whether the proposed rules, in total, creates an environment in which US companies can successfully compete]

- Components/parts and technical data moving off the USML to the CCL may still require export licenses, CCL classification driven. In some cases licence exemptions are available but they still require management and have record keeping demands. These types of goods are freely available throughout Europe and beyond. For example the products QUK design and manufacture for non US customers worldwide, including IR components and parts, can be supplied without US involvement. Many customers demand designs without the inclusion of US technology or hardware both ITAR and EAR to avoid retransfer and export restrictions.

7. [Do the proposed rules follow the ECR guidelines?]

Questions relating to the proposed changes:-

The review is limited to the extent of the technology involvement by QUK. QUK manufactures Major and Minor Components, parts and accessories.

- Ref: End Items enumerated within Cat XII.
  QUK are involved in sections (a) End Item (weapon sights) and module design and manufacture. (c) Weapon sights design and manufacturing incorporating II Tubes and Focal Plane Arrays, ICD data and hardware. (e) Parts, components & accessories in support of US programs (End Items). (f) Currently provided technical data under TAA/MLA approval the scope of which is typically one level down from End Items.

- Q1. Question of Clarity - (a)(2) Contains no reference to specially designed parts and components and section (e)(9) only relates to thermal optics parts and components. This suggests that all other parts other than Camera cores, II Tubes and thermal optics are not controlled under the ITAR regulations, is this correct?

- Q2. Question of Clarity - (c)(12)(ii) The statement is unclear.
  "Output Imagery when subject to more than 20 weapon shock load events of 325g for 0.4ms and a microbolometer IRFPA having greater than 111,000 detector elements"
  What does this mean? And how can it be applied?

- Q3. Question of Clarity (e)(9) Lists - *"Infrared Lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category"*.
  This suggests only the thermal optical parts and components are controlled, all other parts and components used within major and minor thermal components (assemblies eg Objective for weaponsight) are not controlled. Parts such as metalwork housings and spacers, clamp rings etc. These items may fall into 6A615x or y of the CCL. Is this correct?

- **Q4. Question of Clarity - Based upon the assumption of Q3.**

  Scenario : US Company A currently has a TAA with Foreign Company B for the design and manufacture of thermal objectives for a weaponsight. Under US definitions the weaponsight is the End Item the objective is a Major Component.

  Current USML controls - The TAA approves the transfer of controlled data to design the objective assembly for integration within the End Item. The data provided is used by QUK to design the objective, all drawings are controlled under the USML and any companies involved in the manufacture of components or parts must be included within the TAA.

  Proposed USML controls- The TAA will still be required to permit the transfer of controlled data to QUK, as it relates to the End Item. QUK design the objective but only the drawings/data that relate to the thermal optics are stamped as ITAR controlled. All other drawings are not controlled under the USML but may be under the CCL.
  Is this the correct interpretation?

- **Q5. Question of Clarity - (e)(9) Lists - *"Infrared Lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category"*.**
  This suggests only the thermal optical parts and components are controlled and visible optical components are not controlled under the USML. Is this correct?

- **In general the level of detail provided to define category XII is confusing and open to interpretation. For the foreign party to any US program the level of control (EAR or ITAR) and record keeping commitments is likely to increase. It is unlikely that this reform will change the views of many of the Non US customers not to include US technology within their products.**

---

8. [Potential Conclusions]

No comment

If you require any further information, please contact me at [+44 1745588040] or via email at [dave.widdows@uk.qioptiq.com]

Sincerely,

Dave Widdows
Director Compliance
Qioptiq Ltd

From: Zia, Rashid
To: DDTCPublicComments
Subject: ITAR Amendment--Category XII.
Date: Monday, July 06, 2015 3:08:52 PM

To Whom It May Concern:

I appreciate the opportunity to comment on the proposed changes to the USML. I am very concerned about the proposal to place ITAR restrictions on scientific grade cameras. Such changes would present a major restriction on the basic research community in optics and photonics, which has been identified by the US National Academies as "Essential Technologies for Our Nation."

By way of introduction, I hold a tenured faculty position at Brown University, where I am Associate Professor of Engineering and Physics. I received my M.S. and Ph.D. in Electrical Engineering from Stanford University, where I was supported by a National Defense Science and Engineering Graduate (NDSEG) Fellowship. As a faculty member at Brown, I have received a National Science Foundation CAREER Award and a Presidential Early Career Award for Scientists and Engineers (PECASE). (For reference, the PECASE award is “the highest honor bestowed by the U.S. government on scientists and engineers beginning their independent careers.”) As an expert in the field of photonics, I have served as a reviewer for the Army Research Office, the National Science Foundation, the U.S. Department of Energy’s Solid-State Lighting Program, the U.S. Department of Energy’s Office of Basic Energy Sciences, and the U.S. Civilian Development and Research Foundation. I also currently lead a large-scale 5-year, 7.5-million-dollar Multidisciplinary University Research Initiative (MURI) on Quantum Metaphotonics & Metamaterials sponsored by the U.S. Air Force Office of Scientific Research. In the course of our basic research programs, my lab routinely uses scientific grade cameras, including EMCCDS, intensified CCDs, and near-infrared InGaAs focal plane arrays.

As a point of reference, my lab is unable to purchase or use any ITAR controlled equipment. As a whole, Brown University is very hesitant to purchase any ITAR restricted items as restricting their access to foreign graduate students is onerous. As a Principal Investigator, it would be impossible for me to justify the purchase of a scientific tool that could not be used by many of my students. I also know that many of my MURI collaborators (from leading institutions such as Caltech, MIT, Penn, Stanford, UC Berkeley, and UT Austin) share similar concerns and restrictions.

Therefore, I sincerely believe that it would be devastating for the photonics research community if the US government were to place ITAR restrictions on scientific grade cameras, such as intensifier CCD, near-infrared InGaAs and EMCCD cameras. If this were to happen, it will setback US research significantly, especially, in contrast to the researchers in EU and Asia who face no such restrictions from their respective Governments.

If you require any further information, please contact me at 401-863-6351 or via email at Rashid_Zia@brown.edu

Sincerely,

Rashid ZIa
Associate Professor of Engineering and Physics

Brown University

Raytheon

Raytheon Company
1100 Wilson Boulevard
Arlington, Virginia
22209 USA

July 6, 2015

Via Email

Mr. C. Edward Peartree
Director
Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
U.S. Department of State
2401 E Street, NW
SA-1, 12th Floor
Washington, DC 20037

Email: DDTCPublicComments@state.gov

Reference: RIN 1400–AD32

Subject: Review of USML Category XII

Dear Mr. Peartree:

Raytheon Company ("Raytheon") respectfully submits the following comments on U.S. Munitions List ("USML"), 22 C.F.R. §121, Category XII in response to the *Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII*, 80 Fed. Reg. 25821 (May 5, 2015). We applaud your Office's tireless efforts in bringing Export Control Reform to fruition. Based upon our extensive experience as a manufacturer and exporter of fire control, range finder, optical, and guidance and control equipment, we would like to draw the attention of Directorate of Defense Trade Controls ("DDTC") to certain entries in the proposed that we believe require clarification, control items that are in normal commercial use, and/or are unduly complex/burdensome.

Please see our detailed comments below. In addition, Raytheon's comments to the Bureau of Industry and Security's companion proposed rule on *Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the U.S. Munitions List*, 80 Fed. Reg. 25,798 (May 5, 2015) are provided for your reference in **Attachment A**.

Category XII(a) – De-conflict with other USML-controlled fire control systems

Raytheon is concerned that proposed Category XII(a) could inadvertently capture fire control systems that are properly classified under other USML categories. We recommend clarifying the scope of Category XII(a) by including a note.

Currently, fire control systems are enumerated in multiple other places on the U.S. Munitions List ("USML"), including Categories VII(g)(12), VIII(h)(16), IV(h)(1), IV(h)(2), and IV(h)(9), no of with are designated as Significant Military Equipment ("SME"). The proposed rule does not provide clear direction as to which fire control systems are intended to be captured in Category XII(a), which is designated as SME.

Based on Federal Register notices 78 Fed. Reg. 22,740 (April 16, 2013) (Initial Implementation of Export Control Reform) and 79 Fed. Reg. 26 (December 31, 2014) (Continued Implementation of Export Control Reform; Correction), the newer regulations revising the above mentioned USML categories supersede any unrevised categories; and as such, while many of the items now enumerated above may have been Category XII(a) in the past and designated as SME, they are now in categories that are not designated as SME. To capture the remaining related (and often less sophisticated) items in Category XII as SME would be a reversal of direction and introduce competing categories.

We also note that there is an industry best practice, and informally encouraged by the Department, to classify an item in a category that is designated as SME when there are two or more arguably applicable entries and the other candidate entry (or entries) are not SME. As such, without a clarifying note providing additional details as to the types of fire control systems that are intended to be captured in Category XII(a), items that are properly classified elsewhere on the USML may be inadvertently controlled under Category XII(a).

Recommendation: Add a Note to Category XII(a) as follows:

> *Note to paragraph (a): For controls on fire control systems specially designed for integration into a Category IV(a) article, ground vehicle, naval vessel or aircraft, see USML Categories IV(h), VI(f), VII(g) and VIII(h) respectively. USML Category XII(a) is limited to systems for soldier mounted, gun-mounted, fixed infrastructure, or free-standing systems (e.g., tripods).*

Category XII(a) – Recommend removing the SME designation for these items

> Raytheon is concerned that proposed Category XII(a) would control fire control systems as SME. Raytheon notes that other fire controls systems, and ones that are more complex than those within Category XII, are not designated as SME elsewhere on the USML. Raytheon recommends removing the proposed SME designation to be consistent with the treatment of other fire control systems on the USML.

The USML currently controls missile, ground vehicle, and aircraft fire control systems as non-SME. *See* USML Category IV(h)(1), Category IV(h)(2), Category VII(g)(12), and Category VIII(h)(16). These systems often offer sophisticated in-flight guidance to munitions. In contrast gun-mounted fire control systems often offer less sophisticated fire control through displaced reticles. It is inconsistent to control the less sophisticated systems as SME when the more complex systems are not SME.

Recommendation: Remove the proposed SME designation on proposed Category XII(a) to align with Category IV(h)(1), Category IV(h)(2), Category VII(g)(12), and Category VIII(h)(16).

Category XII(b) – Recommend including "specially designed" as a control parameter

> Raytheon is concerned that proposed Category XII(b) would control items that are in normal commercial use. In particular, Raytheon identifies several items below that meet the parameters of proposed Category XII(b) but are in normal commercial use and, thus, should not be controlled on the USML. Raytheon recommends revising the control criteria in Category XII(b) to avoid capturing items that are in normal commercial use.

There are numerous commercial articles that would qualify under the controls within proposed control parameters for Category XII(b). Infrared laser diodes and laser pointers exceeding 1,000 nm have many civil applications as well as target designators. Several examples are provided below. These infrared laser diodes would be controlled by the proposed Category (b)(1) or (b)(2).

There are rangefinders used within modern manufacturing, medical, scientific, and engraving industries that meet the control parameters in Category XII(b)(3). These systems all operate at wavelengths around 1,064 nm because of laser efficiencies and not due to military usage. The power of the laser will drive the overall range of the system. As such, laser power is likely a better indicator of whether the system would have unique military usage.

Further, laser rangefinders in normal commercial use commonly exceed 1,000 nm by virtue of efficient operating wavelengths. One example are the model DBR1064S laser diodes made by Thorlabs, Inc. We have included the laser diode specifications sheet with these comments (see **Attachment B**). These laser diodes operate at 1,064 nm are used in a variety of civilian applications, such as fiber amplifier seeding, second harmonic generation, gain switching, and low-noise pump applications. If the proposed criteria become a final rule, then this item would be a defense article unless the currently proposed performance characteristics are revised.

Additional examples of items in normal commercial use that would be controlled by the proposed USML criteria include:

- Medical: The GentleMax Pro laser is a "single consolidated system that delivers a range of treatments - all skin type hair removal, as well as pigmented and vascular lesions." The GentleMax Pro includes a 1064 nm Nd:YAG laser. If the proposed criteria becomes a final rule, then this item would be a defense article.

  See: http://syneron-candela.com/na/product/gentle-pro-series/howitworks

- Sports: This website identifies numerous general purpose and commercial use laser diodes, such as those used to identify golf balls by golfers, which would exceed the proposed performance parameters. If the proposed criteria becomes a final rule, then these items would be defense articles unless the currently proposed performance characteristics are revised.

  See: http://www.alibaba.com/showroom/golf-rangefinder-laser-diode.html

- Cleaning: This website describes the use of lasers for cleaning purposes for commercial uses. As discussed in the document, pulse duration, pulse frequency, and power dictate the strength and ability for the laser to clean. The product examples included are 1060nm, thus, exceeding the proposed USML threshold.

  See: http://www.logismarket.fr/ip/quantel-lasers-haute-cadence-laserblast-lasers-haute-cadence-440065.pdf

The criteria laid out within proposed Category XII(b) will control most commercial laser systems.

Recommendation: Add the term “specially designed” to proposed USML Category (b)(1), (b)(2), (b)(3), and (b)(4) and add a power requirement criteria.

Category XII(c)(2) – Clarify the meaning of “permanent encapsulated sensor assembly”

> Raytheon requests clarification on the definition of “permanent encapsulated sensor assembly” within proposed Category XII(c)(2). Raytheon recommends that the definition should apply to packaged detectors and not a higher level of integration incorporating camera electronics and provide a protection scheme standard.

We request additional clarification on the definition of “permanent encapsulated sensor assembly.” It is unclear if a “permanent encapsulated sensor assembly” means a packaged detector only or a higher level of integration incorporating camera core electronics. Additionally, it is unclear whether the definition includes some additional protection mechanism to “prevent direct access”, disassembly, and removal of the infrared focal plane array (“IRFPA”). The exclusion of IRFPAs in a permanent encapsulated sensor assembly strongly suggests the importance of such protection mechanisms. Therefore, we recommend adding clarifying language that the assembly must include a protection scheme to meet the definition of “permanent encapsulated sensor assembly.”

We recommend the definition of “permanent encapsulated sensor assembly” within Note 1 to Category XII(c) be revised as follows:

> *A permanent encapsulated sensor assembly (e.g. sealed enclosure, vacuum package, or wafer level packaged detector) is one that makes the assembly inoperable if subjected to typical commercial disassembly.*

Category XII(c)(2) – Revise criteria for IRFPAs peak response and operating temperature

> Raytheon is concerned that proposed Category XII(c)(2) would inadvertently control consumer silicon imaging sensors. In particular, Raytheon identifies below several items that are in normal commercial use, such as for cell phones and digital cameras, and that are not currently controlled on the USML but may, inadvertently, as result of the proposed rule, become so controlled. Raytheon recommends revising the control criteria to avoid capturing items in normal commercial use.

The proposed wavelength range beginning at 900 nm may inadvertently capture certain silicon imaging sensors currently used in cell phones and other consumer digital cameras. The material characteristics of silicon provide the bandgap is 1.12 eV at room temperature and 1.17 eV at absolute zero and the cutoff or peak wavelength is 1107 nm at room temperature and 1059 nm at absolute zero. Consequently, we recommend 900 nm be changed to 1,200 nm.

In addition, we recommend including a temperature based parameter to release certain civil IRFAs that operate above 1,200 nm. Sensors for astronomy use extrinsic silicon IRFPAs that must operate at very low temperatures, *e.g.*, below 13K. For example, the operating temperature for Raytheon's Aquarius astronomy sensor is 8-10K. IRFPAs that operate at temperatures below 20K would be impractical in military applications due to the power and size required to cool them to such low operating temperatures. The addition of performance criteria relative to operating temperatures (*i.e.*, above 20K) would allow for the release of IRFPAs designed for astronomy use from the USML to the Commerce Control List ("CCL").

<u>Recommendation</u>: The control parameters in proposed Category XII(c)(2) should be revised to:

> *Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding **1,200** nm but not exceeding 30,000 nm, **that operate at temperatures above 20K**, and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;*
>
> *Note 1 to Paragraph (c)(2): This paragraph does not control lead sulfide or lead selenide IRFPAs having a peak response within the wavelength range exceeding **1,200 nm** but not exceeding 5,000 nm and not exceeding 16 detector elements, or pyrolectric IRFPAs with detectors composed of any of the following or their variants: Triglycine sulphate, lead-lanthanum-zirconium titanate, lithium tantalite, polyvinylidene fluoride, or strontium barium niobate.*

Category XII(c)(2) – Revise to avoid controlling items in normal commercial use

> Raytheon is concerned that proposed Category XII(c)(2) would control detectors with four or less elements that are in normal commercial use. In particular,

> Raytheon identifies below several such items that are in commercial use and not currently controlled on the USML. In order to avoid capturing commercial quadrant detectors, Raytheon recommends revising the control criteria to adopt the EAR §772.1 definition of Focal Plane Array.

Quadrant detectors are dual-use items and that are readily available in the commercial marketplace. Attached are two brochures that evidence normal commercial use, i.e., the Excelitas YAG-555-(**Attachment C**) and 4AH the First Sensor QP154-Q (**Attachment D**). These items are four element detectors that are designed as general purpose commodities. They would not qualify as a "Focal Plane Array" under the CCL definition. The International Traffic in Arms Regulations ("ITAR"), however, lacks a definition of "Focal Plane Array". To control items such as these that are in normal commercial use is inconsistent with the stated objectives of Export Control Reform to only control those items on the USML that provide a significant military or intelligence advantage to the United States.

In recognizing the dual-use nature of these items, the function and performance capabilities of quadrant detectors have historically been controlled by the Department of Commerce. The Export Administration Regulations ("EAR") controls on focal plane arrays specifically exclude quadrant and other four or less element detectors (*see* EAR § 772.1 for the definition of focal plane array):

> *N.B. This [Focal plane array] definition does not include a stack of single detector elements or any two, three, or four element detectors provided time delay and integration is not performed within the element.*

The proposed Category XII(c)(2) reads as follows:

> *Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefore;*

As proposed Category XII(c)(2) does not use specially designed as a control parameter. Therefore, any four or less element quadrant detector will be controlled on the USML.

<u>Recommendation</u>: Add a Note to Category XII(c)(2) that mirrors the N.B. in EAR § 772.1:

> *Note X to paragraph (c)(2): This paragraph does not control single detector elements or any two, three, or four element detectors provided time delay and integration is not performed within the element.*

Category XII(c)(3) – Clarify the meaning of a one-dimensional photon detector IRFPAs

> Raytheon recommends that proposed Category XII(c)(3) define the number of detector elements in "one-dimensional photon detector IRFPAs" by the number of

cross scan detector elements. Raytheon notes that, as proposed, the application of the proposed control criteria would control items in normal commercial use. We recommend revising the control criteria to avoid capturing these commercial items.

DDTC should clarify that the number of detector elements in "one-dimensional photon detector IRFPAs" would be defined by the number of cross scan detector elements. Such IR scanning arrays are also referred to as "linear TDI" IRFPAs.

Under the proposed control criteria, a 576 x 7 linear TDI IRFPA would be defined as a "one-dimensional photon detector IRFPA" having 576 detector elements after TDI. These IRFPAs are currently commercially available, such as the 576 x 7 linear TDI IRFPA manufactured by AIM Infrarot-Module and the 486 x 6 array manufactured by Sofradir-EC.

As these items are already commercially available, the control criteria should be revised accordingly to only capture those items that are not in normal commercial use and that provide a significant military or intelligence advantage to the United States such that control is warranted under the ITAR.

Recommendation: The control parameters in proposed Category XII(c)(3) should be revised to:

> *One-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 640 detector elements* ***after Time Delay and Integration (TDI)***;

Category XII(c)(5) – Revise the control criteria on microbolometer IRFPAs

Raytheon is concerned that proposed Category XII(c)(5) would control items that are in normal commercial use. Raytheon notes that this is an area where commercial applications are growing significantly and outpacing military uses. Raytheon recommends revising the control criteria to avoid capturing commercial items.

Microbolometer IRFPAs (uncooled, long wavelength thermal detectors) are widely available in the global commercial market. There are a number of foreign manufacturers that export microbolometer IRFPAs for commercial applications without integrating them into a camera core, or camera, and some of these manufacturers currently sell 1024 x 768 microbolometer IRFPA arrays (786,432 detector elements). See Ulis (France) Pico1024 Gen2, 1024x768 (**Attachment E**); GWIC (China) GWIR 0302X1A, 640x480 (**Attachment F**); and, Dali (China) DLC640, 640x480 (**Attachment G**).

2013 Non-US Thermal Detector Manufacturers					
Company	**Country**	**Sensor Type**	**Detector Formats**	**Units Produced**	**Market Share**

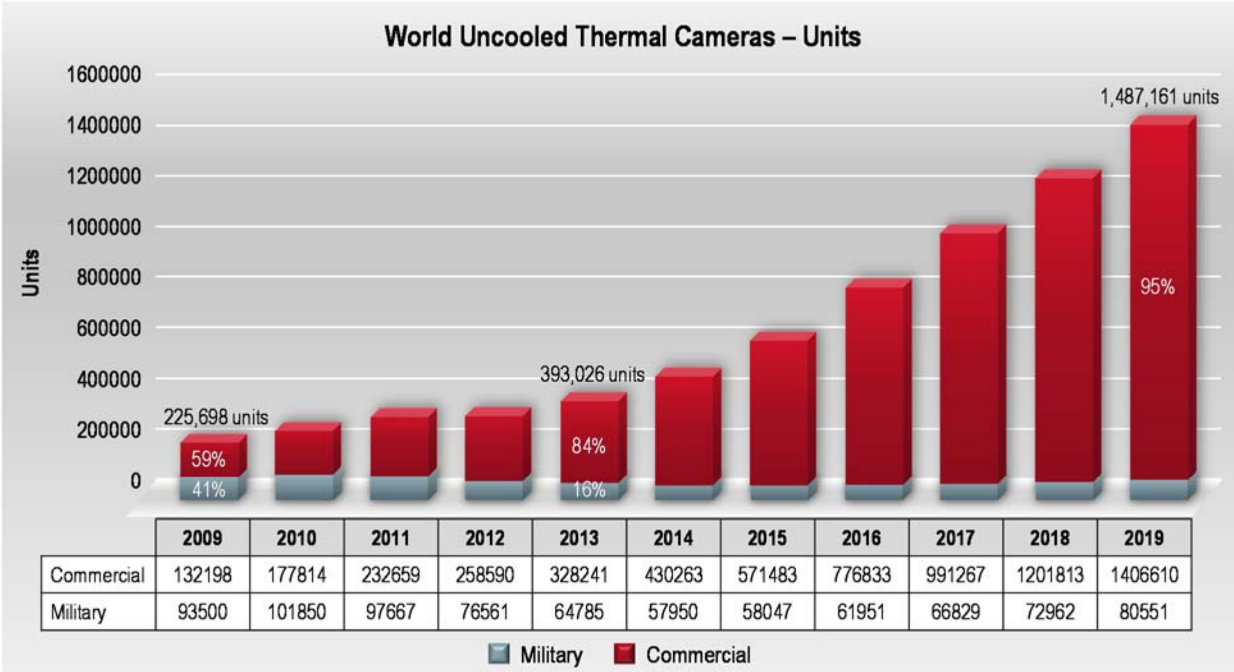
Ulis	France	a-Si microbolometer	80x80	384x288	640x480	1024x768	70,000	18%
GWIC	China	VOx microbolometer	160x120	384x288	640x512		25,000	7%
Irisys	UK	pyroelectric	16x16 to 80x80				17,000	4%
SCD	Israel	VOx microbolometer		384x288	640x480	1024x768	7,000	2%
NEC Avio	Japan	VOx microbolometer		320x240	640x480		6,000	2%
Dali	China	a-Si microbolometer	160x120	384x288	640x480		200 (new market entrant)	0%
TOTAL							125,000	33%
Production and market share: Uncooled Infrared Imaging Technology & Market Trends, Yole Development, July 2014								

Additional microbolometer manufacturers entered the market in 2014, or are expected to enter soon, including: i3system (South Korea); HanVision (South Korea); Teledyne Dalsa (Canada); and Toshiba (Japan).[1] Canada, France, Japan, South Korea and the UK are signatories to the Wassenaar Arrangement on export controls; China and Israel are not. Uncooled thermal detectors and cameras are now widely available from foreign suppliers, and international supply will continue to expand as new foreign thermal detector manufacturers enter the market.

In contrast to other infrared technologies, commercial demand dominants the market for uncooled thermal devices. Currently, commercial sales represent about ninety percent (90%) of the market by volume[2] with about 55% of demand by value outside North America.[3] The total market value for uncooled thermal cameras is about $1.9 billion, with a forecast of about $2.4 billion by 2019.[4]

With expanding commercial sales for automotive, thermography, security surveillance and consumer smartphones, commercial demand is forecast to account for 95% of all thermal camera sales by 2019.[5]

[1] The World Market for Commercial & Dual-Use Infrared Imaging & Infrared Thermometry, Maxtech International, Inc., 2014.
[2] Uncooled Infrared Imaging Technology & Market Trends, Yole Developpement, July 2014.
[3] The World Market for Commercial & Dual-Use Infrared Imaging & Infrared Thermometry, Maxtech International, Inc., 2014.
[4] Uncooled Infrared Imaging Technology & Market Trends, Yole Developpement, July 2014.
[5] Uncooled Infrared Imaging Technology & Market Trends, Yole Developpement, July 2014.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Commercial	132198	177814	232659	258590	328241	430263	571483	776833	991267	1201813	1406610
Military	93500	101850	97667	76561	64785	57950	58047	61951	66829	72962	80551

Source: Uncooled Infrared Imaging Technology and Market Trends, Yole Developpement, July 2014.

However, in order to meet current and future military challenges in multiple mission areas, the United States must maintain a responsive domestic industrial capacity and a competitive edge in the design and production of advanced thermal detectors and other advanced optical sensors. To achieve the economies of scale required to sustain a domestic industrial base, U.S. manufacturers must compete in the expanding international market for commercial uncooled thermal devices. Commercial volumes will help maintain a U.S. industrial base during periods of low U.S. military demand, assure a surge capability in times of U.S. need; maintain a skilled manufacturing workforce, and assure continued investment in R&D, design and manufacturing efficiencies.

As these items are already commercially available, the control criteria should be revised accordingly to only capture those items that are not in normal commercial use and that provide a significant military or intelligence advantage to the United States such that control is warranted under the ITAR.

Recommendation: The control parameters in proposed Category XII(c)(5) should be revised to:

> *Microbolometer IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than **787,000** detector elements.*

Category XII(c)(6) – Revise definition of multispectral IRFPAs

Raytheon recommends that proposed Category XII(c)(6) multi-spectral IRFPAs be defined as IRFPAs that have multiple detectors to address the different spectral

> bands. Raytheon recommends accomplishing this by including a note to Categories XII(c)(2) and (c)(6).

We suggest multi-spectral IRFPAs be defined as IRFPAs that actually have multiple detectors to address the different spectral bands. For example, an IRFPA with stacked HgCdTe detectors for separate spectral bands. Otherwise, the proposed rule could inadvertently capture a spectrally wide, single IRFPA that could be used with multiple filters to detect different wavelengths.

Recommendation: We recommend a note for Category XII(c)(2) and (c)(6) providing:

> *"Multispectral IRFPAs" do not include IRFPAs with only a single detector that employs filters for spectral selections.*

Category XII(c)(9) – Revise control criteria to avoid controlling commercial items

> Raytheon is concerned that proposed Category XII(c)(9) would control items that are in normal commercial use. Raytheon also noted that these items are currently controlled as dual-use items by the EU Dual-Use List and Wassenaar Arrangement. We recommend revising the control criteria to avoid capturing items that are in normal commercial use.

We interpret the proposed rule to mean that specific cryocoolers, even if exported without an IRFPA, are controlled under the USML. This is inconsistent with other regulatory lists where certain cryocoolers are controlled under a dual-use list (*e.g.*, EU Dual-Use List, Wassenaar Arrangement List of Dual-Use Goods and Technologies) rather than under a military list (*e.g.*, WAML, UK Munitions List, etc.). Foreign manufacturers such as AIM Infrarot-Module and Ricor have products that exceed the technical characteristics identified in proposed Category XII(c)(9)(i). Additionally, these manufacturers are subject to less stringent export controls as cryocoolers are treated as a dual-use item outside the United States.

Typically, tactical application or space-qualified Dewars without IRFPAs are not exported, and as such, our recommendation is to only control those IDCAs which incorporate an IRFPA controlled by (a), (b), or (c) of Category XII. Further, it isn't clear what qualifies as "active cold fingers" since it is not a defined term nor widely recognized in the industry. We understand it could be equivalent to "cryocooler".

Recommendation: Category XII (c)(9) should be revised to read:

Integrated IRFPA dewar cooler assemblies (IDCAs) having any of the following:

(i) Variable or dual aperture mechanisms; or

(ii) Dewars ***containing an IRFPA controlled in paragraphs (a), (b), or (c)*** *of this category;*

Category XII(c)(12) – Revise the control criteria to avoid capturing items appropriately controlled by ECCN 6A003

> Raytheon recommends that proposed Category XII(c)(12) release cameras specially designed for the civilian land vehicles described by ECCN 6A003.b.4. Raytheon notes that these commercial cameras already incorporate an active mechanism to limit diversion risk. We recommend two proposed revisions to the control criteria to avoid capturing these commercial items.

We suggest that ITAR control of weapon shock capable cameras should not apply to cameras specially designed for the civilian land vehicles as described in ECCN 6A003.b.4 Note 3 c. because these commercial cameras already limit diversion risk by incorporating an active mechanism that prevents the camera from functioning when it is removed from the vehicle for which it was intended.

Recommendation: Category XII(c)(12) should be revised to read:

Infrared imaging camera cores (e.g., modules, engines, kits), and specially designed electronics and optics therefor, having any of the following:

(i) An image intensifier tube described in paragraph (c)(1) of this category;

(ii) Output imagery when subject to more than 20 weapon shock load events of 325 g for 0.4 ms and a microbolometer IRFPA having greater than ***787,000*** *detector elements;*

(iii) A microbolometer IRFPA described in paragraph ***(c)(2)*** *of this category having greater than* ***787,000*** *detector elements;*

(iv) An IDCA described in paragraph (c)(9) of this category, or IDCA parts or components described in paragraph (e)(7) of this category;

(v) A one-dimensional photon detector IRFPA described in paragraph (c)(2) of this category having a peak response within the wavelength range exceeding ***1,200*** *nm but not exceeding 2,500 nm and greater than 640 detector elements* ***after TDI****;*

(vi) A one-dimensional or two-dimensional photon detector IRFPA described in paragraph (c)(2) of this category having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm and greater than 256 detector elements ***after TDI****;*

(vii) A one-dimensional photon detector IRFPA described in paragraph (c)(3) of this category;

(viii) A two-dimensional photon detector IRFPA described in paragraph (c)(2) or (4) of this category having a peak response within the wavelength range exceeding ***1,200*** *nm but not exceeding 2,500 nm, and greater than 111,000 detector elements;*

(ix) A two-dimensional photon detector IRFPA described in paragraph (c)(4) of this category having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm;

*(x) A multispectral infrared focal plane array described in paragraph **(c)(2)** of this category; or*

(xi) A charge multiplication IRFPA controlled in paragraph (c)(7) or (8) of this category.

Alternative Recommendation: In the event our recommendation on Category XII(c)(12)(ii) is not adopted, then as an alternative we recommend this provision be revised to read:

(ii) Output imagery when subject to more than 20 weapon shock load events of 325 g for 0.4 ms and a microbolometer IRFPA having greater than 111,000 detector elements; ***provided that this provision shall not apply to cameras specially designed for civilian land vehicles as described in ECCN 6A003.b.4 Note 3 c. of the EAR;***

Category XII(c)(17) – Revise control criteria to avoid controlling commercial items

> Raytheon is concerned that proposed Category XII(c)(17) would control millimeter-wave imaging devices that are in normal commercial use. Raytheon notes that the proposed rule would include security screening devices for concealed weapons detection at U.S. and international civilian airports. Raytheon also identifies numerous other civilian applications below for these imaging devices, and notes that the global civilian marketplace for these items is increasing. We recommend revising the control criteria to avoid capturing these commercial items by focusing the parameters at levels not used in civilian applications.

The proposed rule would capture millimeter-wave imaging devices, which have a number of civil applications, including pharmaceutical, biomedical, security, and materials characterization. Millimeter-wave devices represent a potential multi-billion dollar global market.[6] Security screening for concealed weapons detection at U.S. and international airports is the most visible current use of such imaging systems, with an expanding global demand for such public safety screening devices at other public venues. Such systems are available from U.S. and foreign suppliers. The proposed amendment would permit such commercial devices to be controlled under the EAR.

Recommendation: We recommend that Category XII (c)(17) be revised to read:

Terahertz imaging systems or equipment having a peak response in the frequency range exceeding 30 GHz but not exceeding 3000 GHz and having a resolution ***less than 0.1*** *milliradians at a standoff range of 100 m;*

[6] *Millimeter Wave Technology Market by Product and Geography - Forecast to 2020*, MarketsandMarkets, June, 2015.

Category XII(d)(1) Note – Revise to include other Category IV(a) systems

> Raytheon is concerned that the proposed Note to Category XII(d)(1) would introduce duplicate controls. Specifically, Raytheon notes that Category IV(h) is not limited to rocket and flight control and guidance systems as it controls other related guidance systems, such as IV(a)(6) guidance systems. We recommend revising the note accordingly to capture all rocket and flight control and guidance systems articles within Category IV(a).

As written, the proposed Category XII(d)(1) will introduce duplicate controls. Note to Category XII(d)(1) reads as follows:

> *For aircraft and unmanned aerial vehicle guidance or navigation systems, see USML Category VIII(e). For rocket or missile flight control and guidance (including guidance sets), see USML Category IV(h).*

Raytheon notes that Category IV(h)(1) controls rocket and missile flight control and guidance systems. However, Category IV is not limited to only rockets and missiles as it also captures flight control and guidance systems for other Category IV(a) systems. For example, a Category IV(a)(6) bomb flight control system is controlled under Category IV(h)(1).

Recommendation: We recommend changing the note to Category XII(d)(1) to read as follows:

> *For aircraft and unmanned aerial vehicle guidance or navigation systems, see USML Category VIII(e). For flight control and guidance (including guidance sets) for any USML Category IV(a) article, see USML Category IV(h).*

Category XII(e)(3) – Revise or Delete entry as it would control items in normal commercial use

> Raytheon recommends the revision or deletion of proposed Category XII(e)(3). Raytheon notes that imposing new controls on wafers being produced in U.S. foundries will increase costs for U.S. suppliers.

U.S. foundries maintain technology control plans for properly handling ITAR-controlled technical data. However, the proposed rule could be interpreted to require additional controls on the actual wafers that are in the foundries' normal commercial processing flow. Restricting access to wafers in U.S. foundries would impose new costs on U.S. suppliers.

In order to remain competitive, U.S. businesses must keep costs low which may be difficult given the shrinking supplier base for wafers. As defense budgets shrink, U.S. foundries are becoming more reluctant to deal with smaller orders of business that come with significant risks attached. It's possible that control of wafers could eliminate U.S. foundries from competing in this market.

Recommendation: We recommend this entry be revised or deleted.

Category XII(e)(4) and (e)(5) – Combine and revise these entries

> Raytheon recommends combining proposed Categories XII(e)(4) and (e)(5). Raytheon notes that these items are commercially available today and do not provide a military advantage to the United States such that controls under the ITAR are warranted. Combining these two entries would more appropriately control those items on the USML that do provide a significant military advantage to the United States while not injuring domestic manufacturers of commercial items.

In order to remain competitive, U.S. businesses must keep costs low which may be difficult given the shrinking supplier base for wafers. As defense budgets shrink, U.S. foundries are becoming more reluctant to deal with smaller orders of business that come with significant risks attached. Shifting control to the EAR will allow suppliers more flexibility and encourage them to continue to do business with U.S. defense contractors.

As such, controlling these items on the USML is inconsistent with the states objectives of Export Control Reform. Specifically, these items are in normal commercial use and they do not provide a significant military or intelligence advantage to the United States.

Recommendation: We recommend Category XII(e)(4) and (e)(5) be combined and provide as follows:

> *Read-Out Integrated Circuits (ROICs) specially designed for an IRFPA controlled in **USML Category XII(c).***

We also recommend the Note to paragraph (e)(4) be revised so as to provide:

> ***ROICs not** specially designed for an IRFPA controlled in **USML Category XII(c) are subject to the EAR.***

Category XII(e)(6) – Delete entry as it would control items in normal commercial use

> Raytheon is concerned that proposed Category XII(e)(6) would control vacuum packages and other sealed enclosures that are in normal commercial use. Raytheon cites numerous civilian applications for these imaging devices below; and notes that the global civilian marketplace is increasing and that some of the underlying technology is in the public domain. We recommend deleting this entry.

Vacuum packages and other sealed enclosures do not warrant control under the USML because they do not provide any significant military or intelligence advantage to the United States. Vacuum packages or other sealed enclosures are used with IRFPAs in civil applications (automotive sensors, astronomy telescopes, mobile phones cameras, etc.) which, if controlled, would impact the commercial markets for U.S. companies in the future. Foreign competitors are not subject to the same controls on vacuum packages or other sealed enclosures since they are not identified on the Wassenaar Arrangement Munitions List or Dual-Use Goods and Technologies List, UK Control Lists, or EU Regulations.

Additionally, some of the technology associated with vacuum packages or other sealed enclosures that would be ITAR-controlled under the proposed rule has entered the public domain in patents, published patent applications, and other published patent documents filed with the US Patent and Trademark Office.

Issued Patents	
Publication Number	Description
6,479,320	Vacuum package fabrication of microelectromechanical system devices with integrated circuit components
6,521,477	Vacuum package fabrication of integrated circuit components
5,895,233	Integrated silicon vacuum micropackage for infrared devices
8,608,894	Wafer level packaged focal plane array
8,454,789	Disposable bond gap control structures
8,393,526	System and method for packaging electronic devices
8,736,045	Integrated bondline spacers for wafer level packaged circuit devices
8,980,676	Fabrication of window cavity cap structures in wafer level packaging

Published Patent Documents		
ID Number	Description	Patent Filing Number
10-1044	In-situ Plasma Reduction of Tin Oxide for WLP MEMS	61/410454
10-1209	Method to prevent solder wetting to reference pixel shield	61/405621
11-2315	Integrated Bondline Spacers for Wafer Level Packaged Circuit Devices	14/456156
11-2316	Method of Stress Relief in AR Coated Cap Wafers for Wafer Level Packaged IR FPAs	61/692491
12-3287	Vacuum Getter Structure for Wafer Level Packaged MEMS Devices	13/721545
12-3896	Method of forming a patterned coating on a surface without photolithography or masking	14/100048
12-3389	Solder Barrier as Getter in WLP MEMS Package	13/939400

Recommendation: We recommend that Category XII(e)(6) be deleted.

Category XII(e)(7) – Delete entry as it would control items in normal commercial use

> Raytheon is concerned that proposed Category XII(e)(7) would control cryocoolers and related items that are in normal commercial use. Raytheon recommends deleting this entry and, instead, controlling these items within ECCN 6A615.

Cryocoolers and their related parts and components are currently available outside of the United States and are made by foreign manufacturers such as AIM Infrarot-Module and Ricor. Some of these products, such as the SL150 and K353, exceed the technical parameters identified in proposed Category XII (c)(9)(i).

Parts and components for such cryocoolers are not controlled under the Wassenaar Munitions List.

As such, controlling these items on the USML is inconsistent with the states objectives of Export Control Reform. Specifically, these items are in normal commercial use and they do not provide a significant military or intelligence advantage to the United States.

Recommendation: We suggest Category XII(e)(7) be deleted and the referenced parts and components be classified under ECCN 6A615.

Category XII(e)(9) – Coatings and impact on applying specially designed releases

> Raytheon requests clarification within proposed Category XII(e)(9) that the application of a coating, once applied and dried to an item, does not by itself change the jurisdiction of the item. Raytheon notes that this clarification would be consistent with recent guidance by the Department that CARC coatings applied and dried to an item do not, by itself, change the jurisdiction of the item. We recommend including a note to this section in order to provide clarity this point.

DDTC's guidance on performance enhancing coatings has set precedence that even if the coating is itself ITAR controlled, it does not impact the specially designed status of an article unless they provide a unique military capability. See https://www.pmddtc.state.gov/faqs/ecr.html regarding CARC coatings.

CARC coatings that are otherwise subject to Category XIV(f)(5) fundamentally improves the "performance" of the article in question and therefore the article would normally not qualify under release of specially designed ITAR §120.41(b)(3). As such, DDTC has taken the position that performance enhancing coatings do not change the control of the article.

One of the central goals of Export Control Reform is to promote consistent interpretations. Therefore, proposed Category XII(e)(9) should be consistent with DDTC's interpretation of performance enhancing coatings not impacting specially designed status.

If we take a commercial optics and apply a coating, such as an anti-reflective coating, based on DDTC's precedence the optics would not be specially designed under proposed Category XII(e)(9).

Recommendation: In order to be clear and consistent with past guidance we recommend adding a note to Category XII(e)(9) as follows:

> *Note to paragraph (e)(9): The application of a coating, once applied and dried to the item, to modify performance does not qualify the article as specially designed under this paragraph.*

Category XII(e) and (f) – Revise SME designation on technical data and classified articles

> Raytheon notes that it appears the SME designations for classified articles and technical data are incorrect in these proposed paragraphs. As currently proposed, technical data is designated as significant military equipment but classified articles are not. We recommend revising these entries so that technical data is not designated significant military equipment but classified articles are so designated.

As currently proposed, Category XII(f) for technical data is designated as SME. Also, proposed Category XII(e)(15) for classified articles is not designated as SME. This contradicts the treatment of such items in every other USML category. We believe the SME designations were meant to be reversed.

Recommendation: Revise proposed Category XII(e)(15) to be designated as SME in conformance with ITAR § 120.7(b)(2) and revise proposed Category XII(f) to be non-SME in conformance with every other USML category.

Category XII(f), Note 1 to paragraph (f) – Revise to clarify scope and reduce complexity

> Raytheon is concerned that the proposed Note 1 to Category XII(f) would add an unnecessary element of complexity and could result in attempts by manufacturers to create "ITAR-free" models. We recommend revising the note to clarify that only information that is required to meet controlled performance levels, characteristics, or functions remains subject to the ITAR.

The language of the proposed rule specifying that technical data and defense services "*remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR*" adds an unnecessary element of complexity for U.S. exporters. In order to assure compliance, U.S. exporters may consider it advisable to seek review and approval from two separate U.S. regulatory agencies before exporting technical information related to EAR items. This could also be problematic for U.S. manufacturers of ITAR controlled articles that rely on U.S.

component suppliers who may prefer to move to an "ITAR-free" model in order to avoid ITAR compliance costs and risks. "Required" is currently defined under the EAR.

Although the Department has proposed a definition of "Required" within the ITAR, this comment is still relevant because the proposed ITAR definition of "Required" is not yet final and it may be possible that Category XII becomes effective before the proposed definition. As such, DDTC could accept the recommendations here as a temporary placeholder until the ITAR definition of "Required" becomes final.

Recommendation: We recommend this note be revised to read:

> *Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1) of this category, infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2) of this category, integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9) of this category, wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3) of this category, and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (5) of this category, remain subject to the ITAR;* ***provided that such technical data and services refer only to that portion of the information "required" to achieve or exceed the ITAR controlled performance levels, characteristics, or functions, and shall not apply to technology for items subject to the EAR.***

Category XII(f), Note 2 to paragraph (f) – Revise to clarify scope and reduce complexity

> Raytheon is concerned that the proposed Note 2 to Category XII(f) would add an unnecessary element of complexity that could result in manufacturers developing "ITAR-free" models to avoid this control. We recommend revising the note to clarify that only software or information that is required to meet controlled performance levels, characteristics, or functions remains subject to the ITAR.

Although the DDTC recently proposed a definition of "Required" within the ITAR, this comment is still relevant because the proposed ITAR definition of "Required" is not yet final and it may be possible that Category XII becomes effective before the proposed definition. As such, the Department could accept the recommendations here as a temporary placeholder until the ITAR definition of "Required" becomes final.

The proposed rule provides that software and technical data that includes design or manufacturing process descriptions for IRFPAs and detector elements is controlled in (c)(2). Including "detector elements" could make basic technology for an EAR controlled IRFPA ITAR controlled.

For example, the pixel element technology for a microbolometer IRFPA is typically the same regardless of the whether it is for a large array controlled under the ITAR or a small array controlled under the EAR. The technology that is required for a large array ITAR controlled microbolometer IRFPA is in the design and manufacturing processes for the ROIC, wafer level package, and hybridization, rather than in the pixel or detector element.

Recommendation: We recommend this note be revised by adding the following:

Provided that such software and technical data refer only to that portion of the information "required" to achieve or exceed the ITAR controlled performance levels, characteristics, or functions, and shall not apply to software or technology for items subject to the EAR.

Category XII(f) Note to paragraph A of note 2 to paragraph (f) – Revise to clarify scope and reduce complexity

Raytheon is concerned that the proposed Note to Paragraph A of Note 2 to Category XII(f) would add an unnecessary element of complexity and could promote "ITAR-free" models to avoid this control. We recommend revising the note to clarify that the note applies to items subject to the ITAR.

Recommendation: We recommend this note be revised to read:

Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies ***subject to this subchapter*** *or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.*

Thank you for the opportunity to present Raytheon's views concerning Category XII.

If you have any questions concerning this submission, please contact Karl Abendschein, Senior Manager, Global Trade Compliance, at karl.abendschein@raytheon.com or (703) 284-4275 or the undersigned at julia.court.ryan@raytheon.com.

Sincerely,

Julia Court Ryan
Senior Counsel
Global Trade Compliance, Governance

Karl Abendschein
Senior Manager
Global Trade Compliance, Governance

ATTACHMENT A

RIN 1400-AD32: Proposed Revisions to USML Category XII

July 6, 2015

Via Email

Mr. Dennis Krepp
Office of National Security
and Technology Transfer Controls
Bureau of Industry and Security
U.S. Department of Commerce
14th Street and Pennsylvania Ave., NW
Washington, DC 20230

Email: publiccomments@bis.doc.gov

Reference: RIN 0694-AF75

Subject: Review of Fire Control, Range Finder, Optical, and Guidance and Control Equipment No Longer Warranting Control under the U.S. Munitions List

Dear Mr. Krepp:

Raytheon Company ("Raytheon") respectfully submits the following comments on the proposed changes to the Commerce Control List ("CCL"), 15 C.F.R. §774, Supplement No. 1, set forth in the Bureau of Industry and Security's notice of proposed rulemaking entitled, *Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the U.S. Munitions List*, 80 Fed. Reg. 25,798 (May 5, 2015). We applaud your Office's tireless efforts in bringing Export Control Reform to fruition. Based upon our extensive experience as a manufacturer and exporter of fire control, range finder, optical, and guidance and control equipment, we would like to draw the attention of BIS to those proposed entries on the CCL that require clarification or may be overly broad.

Please see our detailed comments below. In addition, Raytheon's comments to the Bureau of Industry and Security's companion proposed rule titled, *Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII,* 80 Fed. Reg. 25821 (May 5, 2015) are provided for your reference in **Attachment A**.

EAR § 772.1 – Clarify the meaning of "permanent encapsulated sensor assembly"

> Raytheon requests clarification on the requirement and definition of "permanent encapsulated sensor assembly" within Export Administration Regulations ("EAR") §772.1. Raytheon believes that the definition should apply to packaged detectors and not to higher level integrations incorporating camera electronics. In addition,

protection schemes requirements should not apply to microbolometer infrared focal plane arrays ("IRFPAs") that are already widely available on the commercial marketplace. Therefore, we recommend revising the control criteria to avoid capturing these commercial items.

We request additional clarification on the requirement and definition of "permanent encapsulated sensor assembly." It is unclear if a "permanent encapsulated sensor assembly" means a packaged detector only or a higher level of integration incorporating camera core electronics. Additionally it is unclear if some additional protection scheme is required to "prevent direct access", disassembly, and removal of the IRFPA. Any article may ultimately be reverse engineered with sufficient time and resources.

We recommend that such a requirement may not be necessary for those IRFPAs that are currently widely available in the global commercial market.

We recommend that a definition of "permanent encapsulated sensor assembly" be added to EAR §772.1 as follows:

A permanent encapsulated sensor assembly (e.g. sealed enclosure, vacuum package, or wafer level packaged detector) is one that makes the assembly inoperable if subjected to typical commercial disassembly.

ECCN 6E001 and 6E002 Related Controls – Recommend revisions to narrow the controls

Raytheon recommends revising the proposed language in the paragraph 3 of the "Related Controls" to Export Control Classification Numbers ("ECCNs") 6E001 and 6E002. Raytheon notes that the intent of these controls appears to be on technology related to the removal of a "permanent encapsulated sensor assembly." The commenting party requested revisions to limit the scope of the proposed controls.

We believe that the intent of these proposed provisions is to control technology related to the removal of a "permanent encapsulated sensor assembly," and believe that the proposed language is overly broad and unnecessary in achieving the intended level of control. For example, the types of information listed in paragraph 3 (e.g., "mechanical dimensions and physical characteristics of the sensor assembly") related to integration are generally in the public domain and published by manufacturers in their in marketing materials.

We recommend that paragraph (3) of the Related Controls section of both 6E001 and 6E002 be revised as follows to more properly focus on removing the controlled items:

(3) Technology ***"required"*** *for* ***removing*** *a "permanent encapsulated sensor assemblies" subject to the EAR, or* ***removing*** *such assemblies* ***from*** *an item subject to the EAR, and* ***removing*** *image intensifier tubes ("IITs")* ***from*** *an item subject to the EAR, including*

> ***removing*** *items subject to the EAR* ***from*** *foreign military commodities outside the United States is subject to the EAR. This technology includes the testing results, operation instructions for a focal plane array* ***removed from*** *a "permanent encapsulated sensor assembly" subject to the EAR, mechanical dimensions and physical characteristics of the sensor assembly provided such information does not include design methodology, engineering analysis, or manufacturing know-how "****required" to operate the removed IRFPAs.***

ECCN 6E990 Technology related to ROICs – Recommend adding a clarifying note

> Raytheon recommends revising the controls to proposed ECCN 6E990 regarding read-out integrated circuits ("ROICs") to limit the scope of the proposed controls to exclude standard commercial foundry designs. Raytheon notes that technology related to standard commercial foundry design or production technology used for ROICs is already available in the commercial marketplace.

Technology related to standard commercial foundry design or production technology utilized for ROICs may not require specific controls considering the foreign availability of standard ROIC products.

ECCN 6E990 would make the design rules and production technology for ROICs subject to substantially tighter control than EAR99, which is currently the case. This technology captured in the new ECCN would include the standard production design rules used in any semiconductor factory. In order to develop or produce these commodities, the product requires design rules from the integrated circuit factory. These commercial design kits, known as process design kits (PDKs"), would now become subject to this much tighter control since they are used in the development and production of this controlled technology. Examples of technology that would now be subject to this control can be found in the following proprietary design manuals from these representative suppliers: SAMSUNG (LN28LPP Technology Design manual), ON Semiconductor (ONC18 PHYSICAL DESIGN RULES), Tower Jazz Semiconductor (CA18 and CR18 Design Rules).

We recommend adding a note to ECCN 6E990 as follows:

> *Technology related to standard commercial foundry designs or production technology utilized for all read-out integrated circuits is not controlled.*

ECCN 6E994 Technology for maintenance, repair, or overhaul of controlled items

> Raytheon recommends revising the controls to proposed ECCN 6E994 to exclude control technology used for both EAR99 items and items controlled with ECCNs of 6A002, 6A003, or 6A990.

We suggest that technology used for both EAR99 controlled items and 6A002, 6A003 or 6A990 controlled items should not be subject to the controls of 6E994. The requirement as proposed is very broad in scope and could capture basic technology for maintenance, repair and overhaul of EAR99 items. We recommend adding a note to ECCN 9E994 excluding technology also used in connection with EAR99 items.

We recommend adding a note as follows:

> *Technology related to maintenance, repair, or overhaul of commodities* ***not*** *controlled under 6A002, 6A003, or 6A990 but that can also be applied to or used for commodities controlled under 6A002, 6A003, or 6A990 is not controlled under 6E994.*

Thank you for the opportunity to present Raytheon's views concerning the proposed revisions to the CCL.

If you have any questions concerning this submission, please contact Karl Abendschein, Senior Manager, Global Trade Compliance, at karl.abendschein@raytheon.com or (703) 284-4275 or the undersigned at julia.court.ryan@raytheon.com.

Sincerely,

Julia Court Ryan
Senior Counsel
Global Trade Compliance, Governance

Karl Abendschein
Senior Manager
Global Trade Compliance, Governance

ATTACHMENT A

<u>RIN 0694-AF75: Proposed Revisions to the EAR</u>

ATTACHMENT A

RIN 1400-AD32: Proposed Revisions to USML Category XII

THORLABS

1064 nm Pigtailed DBR Laser Diode, 20 mW

DBR1064S

Description

Thorlabs' DBR1064S Distributed Bragg Reflector (DBR) laser is a single-frequency laser diode that is well-suited for fiber amplifier seeding, second harmonic generation, gain switching, and low-noise pump applications. The DBR1064S includes an integrated optical isolator, thermo-electric cooler (TEC), thermistor, and monitor photodiode. It is packaged in a 14 pin butterfly package with HI1060 single mode optical fiber and an FC/APC connector.

Specifications

DBR1064S	
LD Reverse Voltage (Max)	2 V
Absolute Max Current	200 mA
Absolute Max Power	50 mW
PD Reverse Voltage (Max)	15 V
Operating Temperature	0 to 50 °C
Storage Temperature	-10 to 65 °C

T_{CHIP} = 15 – 35 °C, T_{BASE} = 25 °C, I_{OP} = 150 mA

DBR1064S				
	Symbol	Min	Typical	Max
Center Wavelength	λ_C	1062 nm	1064 nm	1066 nm
Laser Linewidth	$\Delta\nu$	-	10 MHz	-
Output Power CW @ I_{OP}	P_{OP}	20 mW	-	-
Operating Current	I_{OP}	-	150 mA	200 mA
Mode Hop Range[a]	$\Delta I_{Mode\text{-}Hop}$	-	-	10 mA
Mode Hop Free Range[b]	$\Delta I_{Mode\text{-}Hop\text{-}Free}$	50 mA	-	-
SMSR in Mode Hop Free Range	SMSR	30 dB	50 dB	-
Threshold Current	I_{TH}	-	35 mA	-
Forward Voltage	V_F	-	2.0 V	2.5 V
Slope Efficiency	$\Delta P/\Delta I$	-	0.25 W/A	-
Current Tuning @ I_{OP}	$\Delta\lambda/\Delta I$	-	0.002 nm/mA	-
Temperature Tuning @ I_{OP}	$\Delta\lambda/\Delta T$	-	0.08 nm/°C	-
Monitor Diode Responsivity @ I_{OP}	I_{MON}/P	-	10 µA/mW	-
Internal Isolator Isolation	ISO	32 dB	-	-

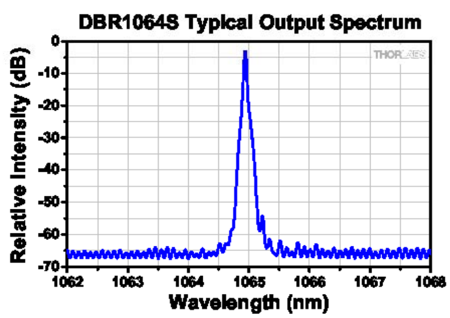
a. Extent of mode hop transition region between single frequency operating points.

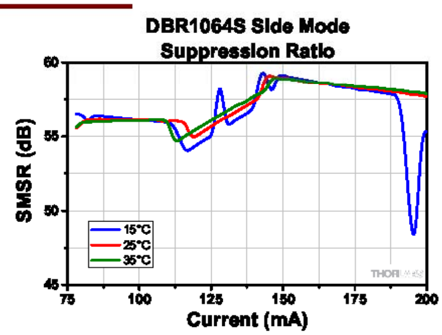
b. Continuous tuning range between mode hops.

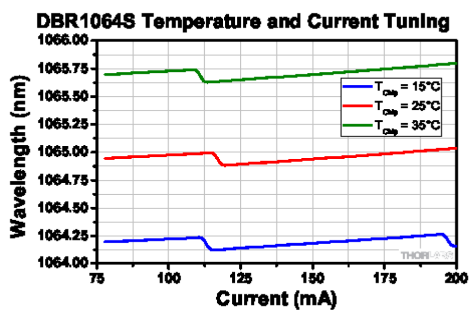
January 20, 2014
QTN006314-S01, Rev A

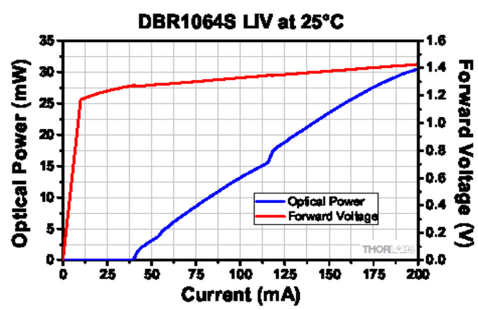
DBR1064S TEC Operation				
	Symbol	Min	Typical	Max
TEC Current	I_{TEC}	-	0.1 A	1.5 A
TEC Voltage	V_{TEC}	-	2.8 V	4.0 V
Thermistor Resistance @ 25 °C	R_{TH}	-	10 kΩ	-

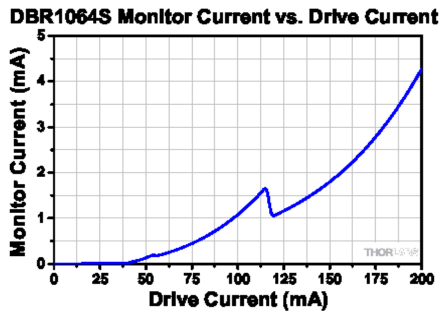
Typical Performance Plots



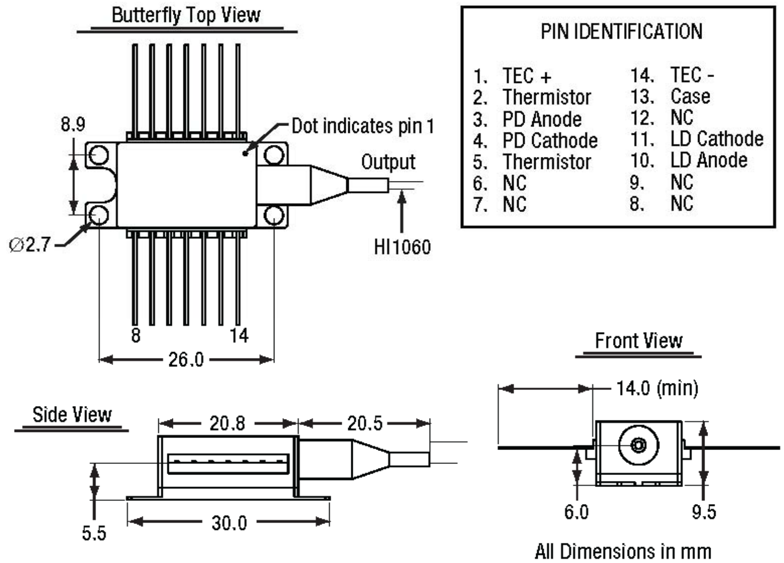








Drawings



PIN IDENTIFICATION	
1. TEC +	14. TEC -
2. Thermistor	13. Case
3. PD Anode	12. NC
4. PD Cathode	11. LD Cathode
5. Thermistor	10. LD Anode
6. NC	9. NC
7. NC	8. NC

ATTACHMENT C

DATASHEET
Photon Detection

YAG series – YAG-444-4AH, YAG-444N-4AH and YAG-555-4AH quadrants

Silicon PIN Quadrant Detector

The YAG series high-performance Si PIN photodiodes are well-suited for applications such as munition guidance, laser spot tracking and others.

Excelitas Technologies' YAG series of Silicon PIN quadrant detectors are high-performance N-type or P-type Si PIN photodiodes in hermetically sealed TO packages. These photodiodes perform well over the 400 nm to 1100 nm wavelength range, with enhanced IR responsivity, making them ideal for 1064 nm detection applications.

A guard ring collects current generated outside the active area, ensuring the current will not contribute to noise.

The YAG-444-4AH, YAG-444N-4AH, and YAG-555-4AH are quadrant photodiodes with circular active area with four pie-shaped quadrant sections created from the doping process, each with an isolated signal lead. There is no "dead" space between the elements.

Recognizing that different applications have different performance requirements, Excelitas offers a wide range of customization of these photodiodes to meet your unique design challenges. Various active area, custom device testing/qualification and packaging options (hermetic metal can, high-shock resistance packaging, ceramic carrier, custom pin-out configuration, heater-options, etc.) are among many of the application specific solutions available.

Key Features and Benefits

- High quantum efficiency at 1064 nm
- Wide spectral range
- Crosstalk <1% between elements
- No "dead zones" between quadrants
- Linearity over wide dynamic range
- Oxide passivated
- Planar diffused structure
- Operation temperature: -55 to 125˚C
- Package style: TO-36
- RoHS-compliant
- Available in N- and P-type configuration
- Available with lead-solder

Applications

- Laser spot tracking
- Munition guidance
- Laser seeker head
- Semi-Active Laser (SAL) sensor

EXCELITAS® TECHNOLOGIES

YAG-444-4AH, YAG-444N-4AH and YAG-555-4AH

Silicon PIN Quadrant Detector

Table 1 – Operating data and specifications at 23°C (typical performance at 180V voltage bias)

	YAG-444-4AH			YAG-444N-4AH PRELIMINARY			YAG-555-4AH			
Parameter (See notes 1 and 2)	**Min**	**Typical**	**Max**	**Min**	**Typical**	**Max**	**Min**	**Typical**	**Max**	**Units**
Number of elements	4			4			4			
Active area (per element)		25			25			39		mm²
Active area, overall diameter		11.5			11.5			14.1		mm
Spectral range					400-1150					nm
Responsivity (See Figure 2) at 900 nm at 1064 nm		0.60 0.44			0.60 0.44			0.60 0.44		A/W
Bandwidth, 50Ω load		60						60		MHz
Rise time		12			12			12		ns into 50Ω
Operating voltage (V_{op})		0-180			0-180			0-180		V
Breakdown voltage (V_{br})	200			200			200			V
Wafer type (See Figure 3) Bias configuration		P-type Common Anode			N-type Common Cathode			P-type Common Anode		
Capacitance		9	15		9	15		12	20	pF
Dark current (I_d)		30	100		30	100		50	150	nA
Channel resistance		>1			>1			>1		MΩ
Series resistance		320						320		Ω
Noise current		0.20			0.10			0.20		pA/√Hz
Noise equivalent power (NEP) 900 nm, 1 MHz 1064 nm, 1MHz		0.25 0.30			0.20 0.25			0.25 0.30		pW/√Hz
Response linearity		<1%			<1 %			<1%		Over 7 decades
Crosstalk		<1%			<1 %			<1%		
Field of View (See Figure 1) Nominal field of view α Nominal field of view α′		110 160			110 160			85 162		degrees

Notes:

1. Active area and all characteristics are listed per element.
2. Breakdown voltage (V_{br}) measurement at 100 µA dark current (I_d), in appropriate polarity depending on wafer type

Figure 1 – Approximate field of view

For incident radiation at angles $\leq \alpha/2$, the photosensitive surface is totally illuminated.
For incident radiation at angles $> \alpha/2$, but $\leq \alpha'/2$, the photosensitive surface is partially illuminated

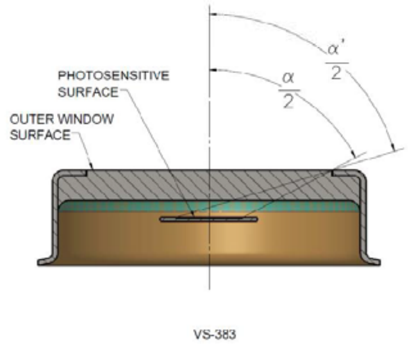


Figure 2 – Typical Spectral Response

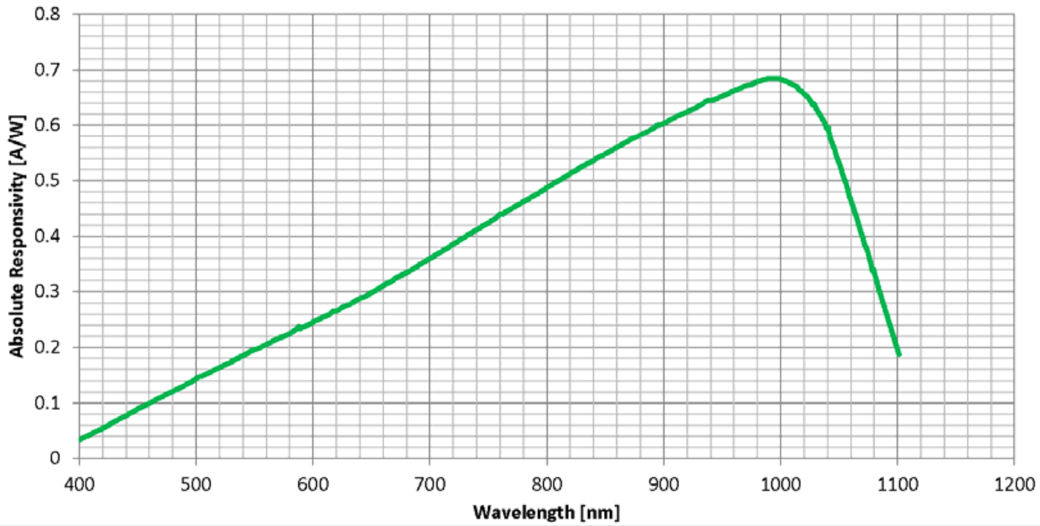
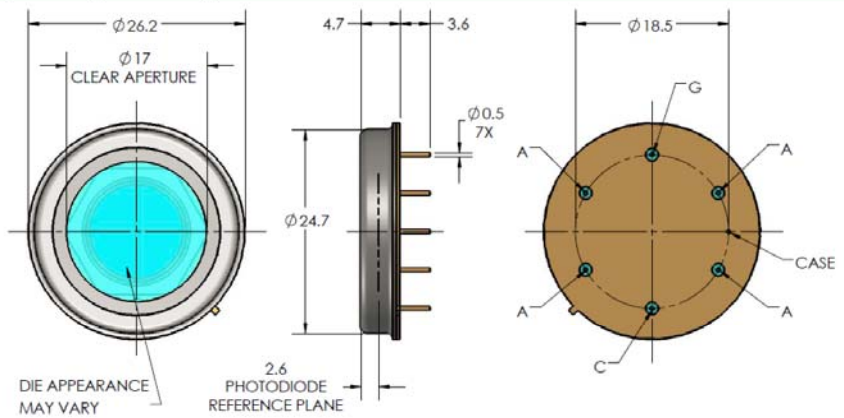


Figure 3 – Package Dimensions and Pin Assignment

Reference only and subject to change without notice



WAFER TYPE	PIN A	PIN C	PIN G
P-TYPE	ACTIVE CATHODE	COMMON ANODE	GUARD RING CATHODE
N-TYPE	ACTIVE ANODE	COMMON CATHODE	GUARD RING ANODE

DIMENSIONS ARE IN MILLIMETERS
VS-362R2

Export controls

Due to specific features some items may be subject to international export controls and may not be exported without official authorization.

RoHS Compliance

The YAG-series of quadrant detectors is designed and built to be fully compliant with the European Union Directive 2011/65/EU – Restriction of the use of certain Hazardous Substances (RoHS) in Electrical and Electronic equipment.

Warranty

A standard 12-month warranty following shipment applies. Any warranty is null and void if the photodiode window has been opened.

About Excelitas Technologies

Excelitas Technologies is a global technology leader focused on delivering innovative, customized solutions to meet the lighting, detection and other high-performance technology needs of OEM customers.

Excelitas has a long and rich history of serving our OEM customer base with optoelectronic sensors and modules for more than 45 years beginning with PerkinElmer, EG&G, and RCA. The constant throughout has been our innovation and commitment to delivering the highest quality solutions to our customers worldwide.

From aerospace and defense to analytical instrumentation, clinical diagnostics, medical, industrial, and safety and security applications, Excelitas Technologies is committed to enabling our customers' success in their specialty end-markets. Excelitas Technologies has approximately 3,000 employees in North America, Europe and Asia, serving customers across the world.

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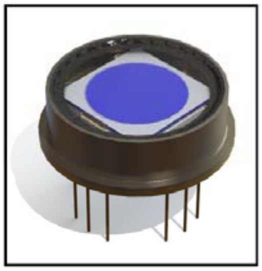
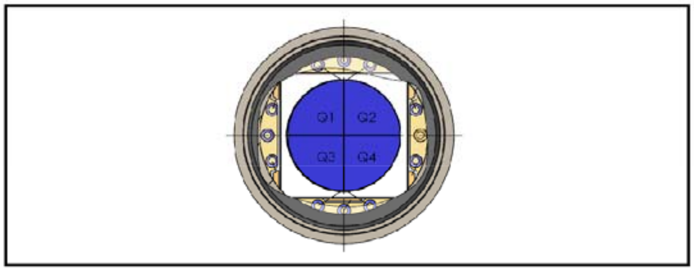
For a complete listing of our global offices, visit www.excelitas.com/locations

ATTACHMENT D





Features

- Quadrant detector
- Low dark current
- Fast rise time, low capacitance
- High QE at 1064 nm
- Including heater and temperature sensor

Description

Circular active area quadrant PIN detector with 14 mm diameter and 70 µm gaps, optimized for 1064 nm. Metal can type hermetic, isolated TO package with ceramic heater and flat clear glass window.

Application

- 1064 nm laser detection
- High speed photometry
- NIR pulsed light sensor
- Laser guidance

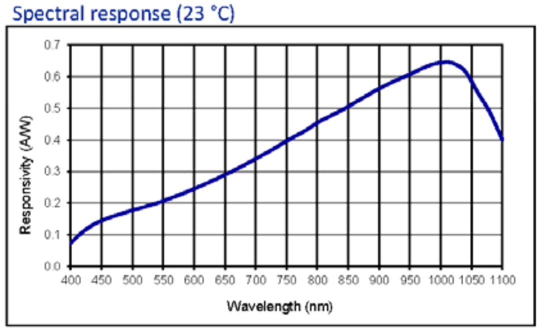
RoHS

2002/95/EC

Absolute maximum ratings

Symbol	Parameter	Min	Max	Unit
T_{STG}	Storage temp	-55	125	°C
T_{OP}	Operating temp	-40	85	°C
V_{OP}	Operating voltage		250	V
I_{PEAK}	Peak DC current		10	mA
p	Outside pressure		5	bar

Spectral response (23 °C)



Electro-optical characteristics @ 23 °C

Symbol	Characteristic	Test Condition	Min	Typ	Max	Unit
	Active area	diameter		14		mm
		per element, number of elements: 4 quadrants		38.5		mm²
	Gap	between elements		70		µm
I_D	Dark current	V_R = 150 V, per element		10	30	nA
C	Capacitance	V_R = 150 V, per element		14	20	pF
	Responsivity	V_R = 150 V; λ = 1064 nm; R_L = 50 Ω	0.42	0.48	0.65	A/W
t_R	Rise time	V_R = 180 V; λ = 1064 nm; R_L = 50 Ω		12		ns
		180 V; 1064 nm; TIA terminated (R_L = 1 Ω)		6		ns
V_{BR}	Breakdown voltage	I_R = 2 µA	250			V
	Temperature coefficiant	Change of I_{PH} with temperature		1.07		%/K
	Cross talk	V_R = 150 V; λ = 1064 nm; R_L = 50 Ω		2		%
	Heating time	23°C to 70°C with 21V power supply	5	6	7	s
	Heater resistance	23°C	36	40	44	Ω
	Temp. sensor resistance	PTC, TK = 3500 ± 200 ppm/K	9950	10000	10050	Ω
	N.E.P.	V_R = 150 V, λ = 1064 nm		1.2E-13		W/√Hz
FOV	Field of view			± 75		°

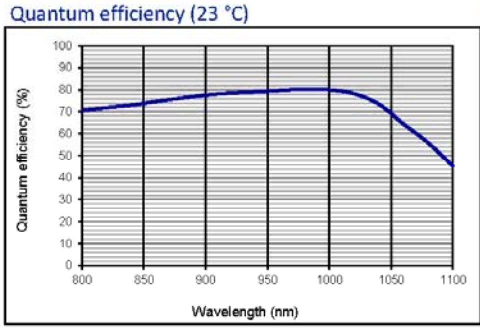
European, International Sales:

First Sensor AG
Peter-Behrens-Strasse 15
12459 Berlin
Germany
T +49 30 6399 2399
F +49 30 639923-752
sales.opto@first-sensor.com

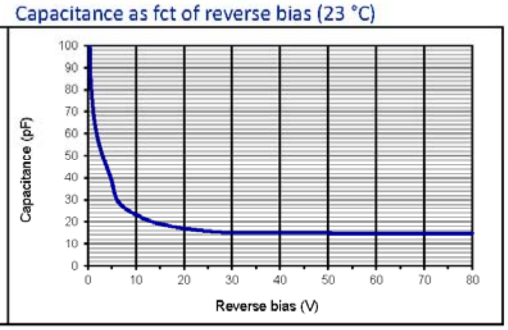
USA:

First Sensor Inc.
5700 Corsa Avenue #105
Westlake Village
CA 91362 USA
T +1 818 706 3400
F +1 818 889 7053
sales.us@first-sensor.com

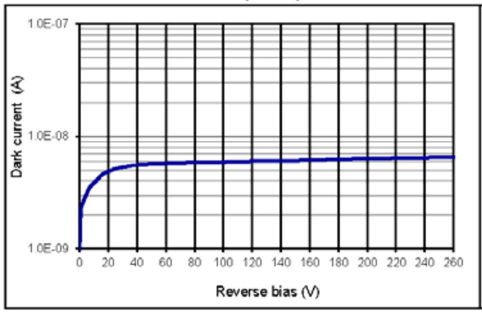
Quantum efficiency (23 °C)



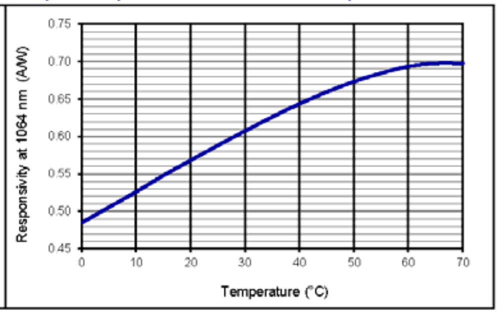
Capacitance as fct of reverse bias (23 °C)



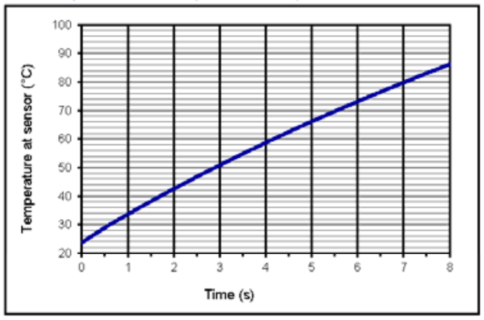
Dark current as fct of bias (23 °C)



Responsivity at 1064 nm as fct of temperature



Heater performance (23 °C, 21 V)



Package dimension:

Small quantities: Foam pad, boxed (12 cm x 16.5 cm)

Source of origin:

This detector and its components are manufactured in Germany.

European, International Sales:

First Sensor

First Sensor AG
Peter-Behrens-Strasse 15
12459 Berlin
Germany
T +49 30 6399 2399
F +49 30 639923-752
sales.opto@first-sensor.com

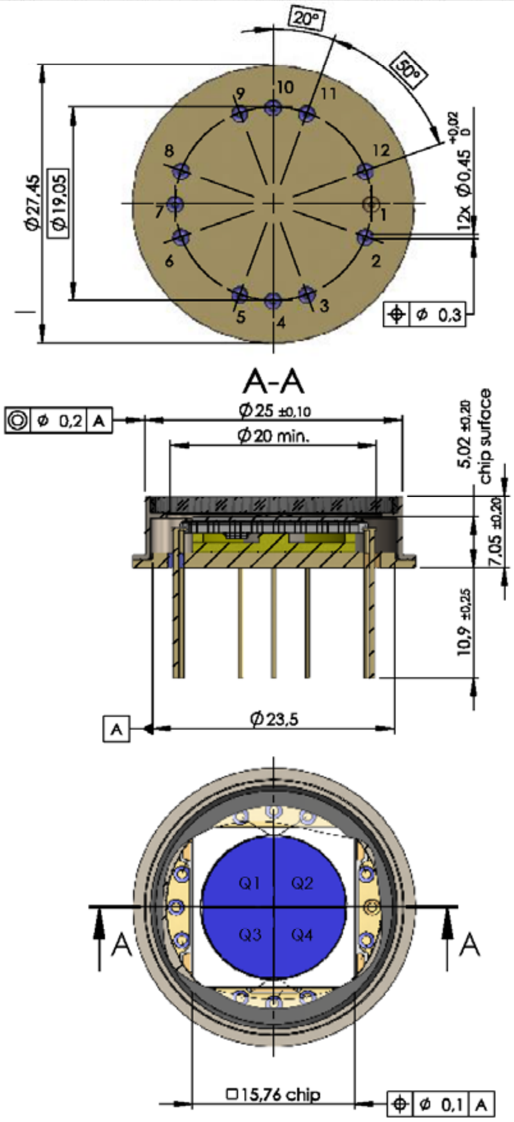
USA:

First Sensor

First Sensor Inc.
5700 Corsa Avenue #105
Westlake Village
CA 91362 USA
T +1 818 706 3400
F +1 818 889 7053
sales.us@first-sensor.com

Technical Drawing

pin assignment												
pin	1	2	3	4	5	6	7	8	9	10	11	12
connection	case	heater 1	Q2	n. c.	Q1	T-Sensor 1	n. c.	T-Sensor 2	Q3	cathode	Q4	heater 2



Disclaimer: Due to our strive for continuous improvement, specifications are subject to change within our PCN policy according to JESD46C.

European, International Sales:
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12459 Berlin
Germany
T +49 30 6399 2399
F +49 30 639923-752
sales.opto@first-sensor.com

USA:
First Sensor
First Sensor Inc.
5700 Corsa Avenue #105
Westlake Village
CA 91362 USA
T +1 818 706 3400
F +1 818 889 7053
sales.us@first-sensor.com

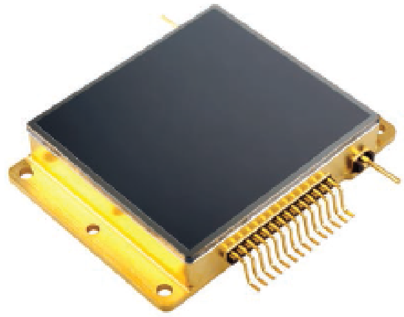
ATTACHMENT E

PICO1024-048

Pico*1024 Gen2*™

1024 x 768 - 17 µm

High performance, high definition infrared imaging



PERFORMANCE

- NETD < 50 mK (F/1, 300K, 30Hz)
- Frame rate up to 120Hz
- Typical array operability > 99.9%
- Low power consumption < 210 mW
- Extended operating temperature range: - 40°C to + 85°C
- Standards: MIL-STD-810 and -883
- Over exposure / Sun safe

FEATURES

- Material: resistive amorphous silicon
- Spectral response: 8 - 14 µm
- Readout configuration driven by serial link
- Overall dimension (mm): 41.2 x 30 x 6.6 pin out excluded
- Weight < 30 g
- Easy TEC-less implementation

+

- High resolution, high contrast imaging for long range detection
- Robust for extreme environments (e.g. TWS, RWS, situation awareness, UGS)
- Detects fast moving objects
- Reduced calibration time
- 24/7 surveillance capable
- Footprint compatible with UL05251-026

ULIS IN BRIEF

- A unique business model designed to serve OEMs
- High production capacity
- High-performance and cost-effective products
- Guaranteed product availability
- Customer partnership to assure success
- A dedicated customer support team

ULIS
Infrared for you

ZI Les Iles Cordées
BP 27 - 38113 Veurey-Voroize - France
Phone: +33 4 76 53 74 70 - Fax: +33 4 76 53 74 80
www.ulis-ir.com - ulis@ulis-ir.com

ELS-02-2015/01

BUREAU VERITAS
ISO 9001
ISO 14001
OHSAS 18001

Groupe SOFRADIR

ATTACHMENT F

中文

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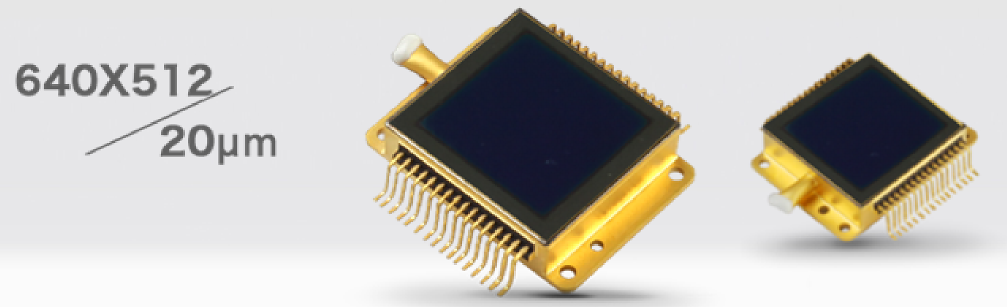
GWIR 0302X1A



	Military	Standard
Material	VOx	VOx
Array format	640×512	640×512
Pixel-pitch	20μm	20μm
NETD(@1/f, 300K, 50Hz)	50mK	80mK
Area fill factor	70%	70%
Spectral response	8-14μm	8-14μm
Thermal time constant	15ms	15ms
Non-operating pixel	<0.1% (the central area of 160X128 without 4 consecutive bad spot)	<0.3%
Typical signal response	12mV/K	12mV/K
Frame rate (Max)	50Hz	50Hz
Dynamic range	≥70db	≥70db
Output signal	Two analog output	Two analog output
Power consumption（excluding TEC）	300mW	300mW
Operating temperature range	-40℃~+60℃	0℃~+60℃
Storage temperature range	-55℃~+70℃	-10℃~+70℃
Weight	25g	25g

Product specifications

North Guangwei Technology INC (GWIC)
North Real Estate Building, No. 81
ZiZhu Yuan Road
HaiDian District, Beijing

ATTACHMENT G

Description

The Uncooled Microbolometer infrared FPA detector researched and developed by Dali has already been applied in industrial production. has the advantages of high resolution, high sensitivity, low thermal noise and fast response. The detector are much suitable for thermography,security surveillance, vehicle night vision and various other applications.

Features

640×480 resolution (17μm)
Frame rate 25~50Hz
High uniformity, low thermal noise
hort integral time, high sensitive
Extended operating temperature range -40℃ to +80℃
Military standard qualification
Fully self-intellectual property

DALI

Zhejiang Dali Technology Co., Ltd. (DALI)
639 Binkang Road
Hangzhou, People’s Republic of China

UNIVERSITY OF CALIFORNIA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO   SANTA BARBARA • SANTA CRUZ

OFFICE OF THE VICE PRESIDENT - RESEARCH AND GRADUATE STUDIES

Research Policy Analysis and Coordination
1111 Franklin Street, 11th Floor
Oakland, California 94607-5200
Web Site: www.ucop.edu/research/rpac/
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July 6, 2015

Office of Defense Trade Controls Policy
Department of State
Washington, DC
email: DDTCPublicComments@state.gov

RE: ITAR Amendment—Category XII

Dear Sirs/Madams,

The University of California (UC) system, consisting of ten research-intensive campuses and involved in the management of three DOE national laboratories, applauds the efforts undertaken by agencies committed to supporting the President's Export Control Reform initiative. We wish to provide comments in response to RIN 1400-AD32, the Department of State's proposed amendment of the International Traffic in Arms Regulations (ITAR) to revise Category XII (Fire Control Equipment, etc.) of the U.S. Munitions List (USML) to describe more precisely the articles warranting control under the USML.

First, we very much endorse the comments made on behalf of the Association of University Export Control Officers (AUECO) in response to this proposed amendment, and to which UC staff and scientists contributed. In particular, we ask that serious consideration be given to the detailed revisions requested in the AUECO comments.

UC is appreciative of the effort to more accurately describe articles within Category XII, transitioning to a positive list and establishing a "bright line" between the USML and the Commerce Control List (CCL). We strongly support the government's intention to avoid the potential harm caused by inadvertently controlling items on the ITAR that are in normal commercial use. However, we are concerned that some of the changes encroach on fundamental research in a manner not seen under the current regulations, and may possibly impose restrictions on publication and/or foreign national participation in such research, both of which are integral to our academic mission.

Our overarching recommendation is that the regulations clearly state that Category XII does not apply to items that are specifically made for non-military end uses, commercial-end uses, <u>and university fundamental research</u> to avoid unintended consequences that would be seriously detrimental to universities, especially those like UC that operate solely within the bounds of fundamental research. Though we believe that the parameters outlined in the proposed rule are intended to appropriately catch items that absolutely need to be controlled under the ITAR, many are too broad and inadvertently include items that are not inherently military, and may be used in fundamentally different ways in academic research.

For example, under the proposed rule, new controls would be added to the broad category of "developmental imaging systems funded by the Department of Defense." However, universities are often involved in DOD-funded fundamental research in these areas, without a project-specific intent of developing systems for a military end use. Funding by the Department of Defense alone should not be the determining factor for export classification. Another example is university fundamental research on lasers and laser systems funded by the Department of Defense. Although Note 1 to paragraph (b)(14) allows for an exception for commercial use, there is no explicit statement that university fundamental research would meet this qualification. We believe that lasers not meeting the requirements for a military end use should not be controlled under ITAR. Thus, a clarification that Category XII does not apply to university fundamental research would be tremendously useful and would additionally promote the benefits described within the proposed rule.

We also urge a clarification to the proposed definition of "development" (80FR 31525), which states "all stages prior to serial production, such as: design…." We are concerned that such definition could be interpreted to include basic or applied research used in the design. A clarification that "development" explicitly excludes fundamental research is needed in order to avoid over-application of the term.

We are further concerned that in many instances these proposed rules will move EAR items to the USML, impacting academic study in non-defense-related areas, such as medical and astronomical research. We are equally concerned with the unfortunate direct effect of adding new controls to items which were formerly not under ITAR jurisdiction, nor listed on the CCL, such as EAR 99 items.

For example, the classification of infrared sensors would include tools modified for use in non-defense-related medical research, such as night vision technology to study light sensitive retinal eye tissue under a microscope. In fact, university research has contributed to some of the best ideas in single photon detection. The work has significant scientific interests because such capability is critical to quantum communications and quantum information technology. The same ultra-sensitive detectors that can detect photons of any wavelengths (from far infrared to x-ray to particles) can also be applied to many non-defense research areas, including focal plane array, LIDAR (Light Detection and Ranging), night vision, infrared cameras, biosensing, medical imaging, non line-of-sight free space communication, etc. The proposed regulations would inadvertently trigger ITAR controls, forcing many universities that operate within the boundaries of fundamental research, such as the University of California, to either make use of inferior non-controlled hardware or to forgo important fields of research altogether to the detriment of the greater public good.

We recommend that items that do not contain military level components, such as military weapons mounting, stability software, and special packaging, should not be ITAR controlled, and that criteria along those lines should be used for distinguishing between EAR and ITAR controlled night vision technology instead of Focal Point Arrays (FPA) and Image Intensifier Tubes (IIT) Generation. It is our understanding that commercial availability of night vision components and equipment at all size ranges for uncooled FPAs, uncooled cameras, and IIT imagers is widespread, and not limited to U.S. Military contractors.

Other examples of items which are commonly used in astronomy in the development/production of land-based telescopes, and which would be ITAR controlled under the proposed regulations are InfraRed Focal Plane Arrays (IRFPA) and dewars, cooling systems, electronics and optics(see XII(c)(2)-(12)). These telescopes have a scientific purpose and do not have a military end use. Whereas the IRFPA technology has expanded to cover nearly all wavelengths and these components are easily commercially available, the proposed regulations seem to move in the opposite direction. We urge the Department of State to consider moving away from using infrared bands as the base for establishing restrictions. Universities routinely use infrared hardware that is commercially sourced or designed in university laboratories in novel ways that may very well meet the infrared band parameters of control, even though the items themselves would not be controlled.

We are also concerned that if items under XII(c)(2)-(9), XII(e)(7) and XII(e)(10) are attached to a controlled IRFPA (such as in a land-based astronomical telescope), the individual items could be considered ITAR controlled, even though some of these components are EAR99. For example, common EAR99 commercially available components used for cooling astronomical focal planes include Pulse-tube cryocoolers, Gifford-McMahon cryocoolers, sorption refrigerators, adiabatic demagnetization refrigerators, and dilution refrigerators. Moving these items to the ITAR would present an extreme burden on universities, and may potentially impose restrictions on publication and participation of foreign nationals in fundamental research, with no real defense security benefit.

Finally, given that existing six-meter telescopes and observatories, such as the Keck and the Large Binocular Telescopes, may already exceed the technical parameters at XII (c)(17), we recommend that these levels be increased, and that the mirror size be increased to greater than 8.4m. Moreover, it bears mentioning that many existing ground based astronomical sites are in foreign countries, such as Chile, the Canary Islands, and South Africa. A broadening of the applicability of ITAR controls to items commonly used at these facilities would affect multi-national collaborations in these areas.

Thank you for this opportunity to comment. We greatly appreciate your efforts to seek input regarding the amendment to Category XII of the USML.

Sincerely yours,

Wendy D Streitz

Wendy D. Streitz
Executive Director
Research Policy Analysis & Coordination
Office of Research & Graduate Studies

Thank you for considering my comments on the proposed changes to the U.S. Munitions List Category XII. Let me begin by noting I fully understand and appreciate that certain items of military significance need export controls to keep them from falling into the hand of our adversaries. Still, items widely available world-wide and treated elsewhere as dual-use should not be placed on the ITAR – yet that is what the proposed regulation does. ITAR export controls impose a significant burden on U.S. industry, stifle creativity, drive customers to our foreign competitors, and thus weaken industry in the U.S., thereby doing significant harm.

Following the request that comments on these proposed revisions be specific, below I discuss how the proposed revisions to the U.S. Munitions List Category XII capture a wide swath of InGaAs focal plane technology that is used for multiple commercial applications and that is available world-wide, including from the PRC, I list commercial applications, I describe the negative impacts this would cause to my business, and I offer some recommendations.

Technology Captured.

Paragraph (c)(2) captures infrared focal plane arrays that are NOT INTEGRATED INTO A PERMANENT ENCAPSULATED SENSOR with a peak response greater than 900 nm but less than 30,000 nm. Item (c)(4) captures those focal plane arrays described in (c)(2) that ARE IN A PERMANENT ENCAPSULATED SENSOR that have greater than 256 detector elements (pixels). InGaAs focal plane arrays typically have a response between 900 nm and 1,700 nm (this wavelength range is extended for some arrays, but they would still be captured by the spectral range defined in (c)(2)). Thus, taken together, (c)(2) and (c)(4) include ALL InGaAs focal plane array technology with more than 256 pixels.

There are a substantial number of foreign providers of InGaAs based sensors and cameras, many considered dual use I believe, and covered by (c)(4). Below is a list of foreign suppliers with their websites and InGaAs products captured by (c)(4) or (c)(2):

1. Xenics (Belgium) www.**xenics**.com/
    a. Xeva-2.35-320 (extended spectral range, 320x256 pixels)
    b. Bobcat-1.7-320 (320x256 pixels)
    c. Bobcat-320-Gated (320x256 pixels with integration times down to 80 ns)
    d. Bobcat-640-CL (640x512 pixels, CameraLink interface)
    e. Bobcat-640-GigE (640x512 pixels, GigE interface)
    f. Cheetah-640CL (640x512 pixels, framerates up to 1,730 Hz)
    g. Cheetah-640CL TE3 (Cooled version of the Cheetah)
    h. Cougar-640 (640x512 pixels, LN2 cooled for low noise)
    i. Meerkat-Fusion (1600x1200 VNIR, 320x256 InGaAs, 384x288 bolometer combination imager)

j. Pumair-170DW (640x480 microbolometer and 640x512 InGaAs dual camera)
k. Rufus-640-Analog (640x512 pixels)
l. XFPA-1.7-640-LN2 (640x512 InGaAs bare detector)
m. XS-1.7-320 (320x256 pixels)
n. XSW-640 (640x512 pixels, OEM version)
o. Xeva-1.7-320 (320x256 pixels)
p. Xeva-1.7-320 TE3 (320x256 pixels, additional cooling)
q. Xeva-1.7-320 VisNIR (320x256 pixels, extended spectral range)
r. Xeva-1.7-640 (640x512 pixels)
s. Xlin detector series (512x1; 1024x1; or 2048x1 linear arrays, speeds up to 40,000 Hz)
t. Xlin-1.7-3000 (3x1024 linear array)

2. Andor (UK) http://www.andor.com
   a. iDus InGaAs 491 array series (1x512; 1x1024 linear arrays)
3. Photonic Science (UK) www.**photonic-science**.co.uk
   a. High Resolution InGaAs (640x512 pixels, extended spectral range)
   b. Cooled High Sensitivity InGaAs (320x356, extended spectral range)
4. Stemmer Imaging (UK) www.**stemmer-imaging**.co.uk
   a. AV Goldeye SWIR (320x256 pixels, at least 2 versions)
   b. AV Goldeye SWIR (636x508 pixels, at least 5 versions)
5. Raptor Photonics (N. Ireland) www.**raptorphotonics**.com
   a. Ninox 640 InGaAs (640x512 pixels)
   b. Owl (both 640x512 and 320x256 pixel versions)
6. Alcatel-Thales III-V Lab (France) http://www.3-5lab.fr/ (Foundry, InGaAs products not listed, but they are a known supplier of InGaAs focal plane arrays)
7. Nip (S. Korea) http://www.nip.co.kr
   a. PHK03M100CSV0 (640x512 pixels)
   b. PHK008M300CSV (320x256 pixels)
   c. THKIK32CSW (1024x1 pixels, linear array)
   d. THK2K10CSW (2048x1 pixels, linear array)
8. Artray (Japan) http://www.artray.us/
   a. 031TNR (640x512 pixels)
   b. 088TNIR (320x256 pixels)
   c. 0016TNIR (128x128 pixels)
9. Hamamatsu (Japan) www.**hamamatsu**.com
   a. G12242-0707W (128x128 pixels, bare)
   b. G11097-0707S (128x128 pixels, chip)
   c. G11097-0606S (64x64, bare)
   d. Other InGaAs offerings as well
10. Chungwa Leading Photonics Tech (Taiwan) http://www.leadinglight.com.tw/

   a. Foundry with 320x256 and 640x512 products.

11. Ghopto (China) http://www.ghopto.com/
   a. SWIR FPAs (bare focal plane arrays)
   b. GHSW320 (320x256 pixels)
   c. GH-SW640 (640x512 pixels)

The point of this long list is that InGaAs cameras covered by (c)(4) and (c)(2) are widely available on the international market. (In fact, a quick check just showed InGaAs cameras on eBay that would be captured by (c)(4).) These suppliers provide InGaAs focal plane arrays and/or cameras which far exceed the 256 pixel limit specified in (c)(4). The most typical arrays formats are: 320 by 256 (81,920) pixels and 640 by 512 (327,680) pixels. To the best of my knowledge, Hamamatsu is the only one of these companies that provides an InGaAs focal plane array with fewer than 256 pixels, indicating that (c)(4) covers nearly all of the InGaAs cameras available world-wide.

Commercial applications.

On Page 9 of the Dept. of State document RIN 1400-AD32, titled "Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII," the following statement can be found:

A note is added to paragraph (c) to address the incorporation of these defense articles into commercial items. With minor exceptions, all bare IRFPAs are controlled in Category XII, paragraph (c)(2). However, once an IRFPA has been incorporated into a permanent encapsulated sensor assembly, it ceases to be controlled in paragraph (c)(2) because it is incorporated into a higher order assembly. The permanent encapsulated sensor assembly will be controlled in paragraphs (c)(3) – (6), if it meets the control parameters of one of those paragraphs. These control parameters are set at a level that the Department has determined excludes most commercial products. Further, once most IRFPAs and permanent encapsulated sensor assemblies are incorporated into a camera core, monocular, or binocular or other higher order system, that system will not be subject to the ITAR or require authorization from the Department for export, unless it is specifically enumerated.

The highlighted statement suggests the control parameters capture very little commercial activity. In fact, (c)(4) captures a substantial portion of a commercial sorting industry (recycled plastics), as well as a portion of commercial food sorting, plus systems used for process control and in mining.

Regarding plastic sorting, a good reference can be found at:

http://plastics.americanchemistry.com/Assessment-of-Commercially-Available-Automated-Sorting-Technology

The companies that utilize InGaAs sensors for their plastic sorting instruments that would likely be covered by (c)(4) include:

1. Rofin Australia Paty Ldt. (Melbourne Australia)
2. MSS (Nashville, TN)
3. Pellenc (Pertuis, France)
4. Titech (now Tomra) (Asker, Norway)
5. Eagle Vizion (Quebec, Canada)
6. Visys (Australia)
7. Best (also Tomra now) (Asker, Norway)
8. NRT (Nashville, TN)
9. Eveready Manufacturing (Singapore)
10. BT-Wolfgang Binder GmbH (Gleisdorf, Austria)
11. RTT Steinert GmbH (Koln, Germany)

In total, there are 12 providers of commercial plastic sorting machines, 9 of which are foreign (8 if you recognize that Asker owns both Best and Titech). Exact deployment numbers are not known, but it is my understanding that TiTech (Norway) alone has sold more than 1,000 systems.

For food sorters (nuts and potatoes, and possibly more), commercial sorting systems that would fall under (c)(4) are provided by:

1. Key Technology Walla Walla, WA
2. EVK Di Kerschhaggl GmbH Raaba, (Austria)

InGaAs focal plane arrays that would be encompassed by (c)(4) are also used to monitor paper manufacturing and for mining (see short descriptions at: http://www.specim.fi/index.php/products/industrial)

My company markets to these industries and we know what the customers ask for. All our products with InGaAs focal plane arrays would be captured by (c)(4), and thus we would have a severe handicap competing in some of most lucrative markets for machine vision, Europe and Japan, as they are affluent economies with a high cost of labor. We have substantial direct competition in both Europe and Japan.

Note: Most of the commercial applications, such as sorting, require high-resolution, high-speed imaging. Consequently, using InGaAs cameras not be encompassed by (c)(4) (256 or fewer pixels (16 x 16 in a square format)) would result in a system with insufficient resolution to meet sorting requirements. In fact, there is substantial commercial pressure to utilize higher resolution and faster InGaAs cameras than are currently available.

Note: The commercial applications listed above happen to be the ones I am aware of, as they are ones where my company's products can be used. It is almost certainly not a complete list of the commercial applications for InGaAs technology captured by (c)(4).

Impacts on my business.

Having InGaAs cameras with more than 256 pixels on the USML would severely limit my company's ability to provide products to foreign existing markets, such as recycled plastic sorting and commercial food sorting, as well as closely related and promising similar commercial applications such as quality control (pharmaceuticals and cooked/processed foods) and precision agriculture.

The negative impacts of International Traffic in Arms Regulation (ITAR) controls on my business includes the higher cost of compliance, (i.e., learning how, or paying to, obtain an export license), the additional time delay needed to obtain the licenses, and the impact on my potential customers who must provide paperwork for licenses.

If the proposed rule is agreed to, then we would have a significant disadvantage in markets where we have foreign competition – this includes Europe, Japan (direct competitors), and to a lesser extent Australia and Canada (similar but differentiated product competitors), because the ITAR does not provide the license exceptions and flexibility that the EAR does. These regions encompass our best foreign opportunities. We will have similar problems in other countries where munitions items are prohibited while dual-use items are not.

In summary, the proposed changes to the United States Munitions List (USML) will add cost, introduce delays, but most importantly, burden our customers in ways our foreign competition will not. As a result, if this proposed rule is implemented, the U.S. government is effectively ceding the largest commercial opportunities with InGaAs cameras to foreign companies.

Lack of "Bright Line"

The proposed language does not create a "bright line" for items (16)(v) and (16)(viii). The text is included below for reference.

> (16) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor:
>
> (v) Multispectral imaging systems or equipment that either incorporate a multispectral IRFPA described in paragraph (c)(2) or (6) of this category, or classify or identify military or intelligence targets or characteristics;
> (viii) Incorporating mechanism(s) to reduce signature; or

In particular, the statement “classify or identify military or intelligence targets or characteristics” does not provide a bright line. Imaging systems, infrared or not, will record an image of the object you put in front of them. Thus, if one puts a tank or a terrorist in front of the imager, these objects will be imaged, and from that one could determine the tank’s shape and possibly identify the terrorist’s face, which I assume would be “military or intelligence targets or characteristics.”

Thus, this clause could effectively include pretty much any camera that records an image and outputs data to a computer. Thus the vague language of (16)(v) makes it essentially impossible to know whether or not a system would be encompassed by (16)(v).

Item (16)(viii) is also unclear to me because I do not know what the term “signature” means in this context.

Summary

The proposed language in the Dept. of State document RIN 1400-AD32, titled “Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII,” for Category 12 does not meet the stated objectives of Export Control Reform.

Rather than capturing the “crown jewels”, InGaAs cameras that would be covered by (c)(4) are widely available internationally (and are even offered on eBay), and thus controlling US exports would provide little containment of the technology. The proposed rule misrepresents or misunderstands the extent to which these cameras are used in commercial applications, and also the number of cameras that would be impacted by the rules. The impacts of including InGaAs on the U.S. Munitions List would impose significant burdens on U.S. companies for a variety of commercial applications, as well as effectively cede new opportunities with this technology to our foreign competitors. Additionally, at least some of the language fails to provide the “bright line” between ITAR and non-ITAR items.

Recommendation

I would recommend abandoning the USML proposed rule as well as the Commerce Companion rule in favor of the existing language in Category 12 for the following reasons:

1. The proposed language captures existing civilian SWIR cameras as well as future ones.
2. The proposed language does impact existing civilian commercial markets as well as future commercial markets.
3. Parts of the proposed language are ambiguous and could lead to commodity jurisdiction filings.
4. The proposed language does not meet the objectives of ECR which is higher fences around fewer items.

5. The proposed language does not provide military parameters, rather it relies on parameters like detector count and wavelength.
6. The 120+ page companion rule is too complex. It appears to remove important license exceptions and destinations as well as create new ECCNs that would require me to hire additional staff to review and keep up the language which would dissuade me from wanting to seek exports for my products.

I would suggest that if another attempt is made at revising the language, it should start with the existing language in Category 12, and then adapt language carefully so as to not capture widely available products, especially those with existing commercial applications.

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July 6, 2015

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Subject: Comments on Proposed Rule to Revise USML Category XII
80 *Fed. Reg*. 25,821 (May 5, 2015); RIN 01400-AD32

Email: PublicComments@state.gov (ITAR Amendment-Category XII)

Comments on Proposed Rule to Revise Individual Export Control Classification Numbers regarding Fire Control, Range Finder, Optical, and Guidance and Control Equipment that No Longer Warrant Control under the USML and to Transfer Items Subject to the EAR to the USML
80. *Fed. Reg*. 25798 (May 5, 2015); (RIN 0694-AF75)

Email: publiccomments@bis.doc.gov

Ricor USA Inc., a subsidiary of Ricor Cryogenic & Vacuum Systems Ltd. (collectively "Ricor"), appreciate the opportunity to provide comments on the proposed revision of USML Category XII published by the Department of State, Directorate of Defense Trade Controls ("DDTC") and by the Department of Commerce, Bureau of Industry and Security ("BIS") regarding revisions to multiple ECCNs applicable to the range of products identified in the title of the proposed rules. As reviewed in detail below, the adoption of these proposed rules would severely hamper the ability of U.S. manufacturers of infrared based devices to compete in the international marketplace for infrared focal plane arrays and cryocoolers and, at the same time, would impose regulatory barriers to foreign manufactures supplying these products to U.S. manufacturers for incorporation in commercial equipment for export markets.

Ricor is a world-leader in cooling-systems found in a wide range of military aerospace equipment and systems and commercial products and solutions, including in semiconductor manufacturing equipment and diagnostic tools, x-ray and gamma detectors, health and safety equipment and scientific instrumentation. Cryocoolers designed, developed and manufactured by Ricor enable the functionality of infrared sensor-based equipment in commercial devices for: spectrographic analysis, germanium detectors incorporated into cargo and other inspection equipment, gas detection, furnace inspections, infrared microscopes, radioisotope identification, and for thermal conductivity testing and imaging. Our comments are directed toward the proposed revision of existing controls on cryocoolers.

In the sections that follow, we

(1) Present specific revisions to the proposed DDTC and BIS regulations,

(2) Document the largely unrestricted foreign availability of cryocoolers similar to those manufactured by Ricor, assess the negative impact of transferring jurisdiction over cryocoolers from the EAR to the ITAR and imposing ITAR controls on the export and reexport of cryocoolers, integrated IRFPA dewar cooler assemblies ("IDCAs") and commercial equipment that incorporates IDCAs with cryocoolers,

(3) Suggest that if export controls applicable to cryocoolers are to be redraft, the export agencies should minimize the unilateral trade limiting effects of ITAR controls on the U.S. commercial industry that incorporate IDCAs in their products and on other manufacturers in other countries that adopt controls similar to those maintained by the United States. The appropriate forum for establishing multilaterally-agreed to controls is among the members of the Wassenaar Arrangement.

I. Overview

As a company with a worldwide customer base, we are acutely aware of the defense, commercial and dual-use export controls that apply to our products by multiple export control regimes. Export control compliance has been integrated throughout Ricor's international operations. By competing in global markets we have become aware that certain other countries do not follow similar standards for reviewing proposed export transactions and approve the sale of cryocoolers to commercial customers that would not be authorized by the United States. In order to address this issue, the proposed regulations would establish a set of criteria that would largely render uncompetitive in global markets U.S.-origin equipment that incorporate IDCAs with cryocoolers. By restricting severely U.S. exports of commercial products, the U.S. share of the global market will continue to decrease, thus restricting the long term competitiveness of the U.S. industry to design and manufacture IDCAs for commercial and military products.

II. Suggested Modifications to the Proposed Regulations

With respect to the ongoing Export Control Reform ("ECR") initiative, we believe that our familiarity with the global marketplace for cryocoolers and the proposed revisions to the USML and CCL, enable us to propose the following modifications to the proposed regulations.

A. Expand the Scope of Note 2 to Proposed USML Paragraph (c) to include "Integrated IRFPA dewar cooler assemblies (IDCAs)" with cryocoolers (with stated performance characteristics) and "active cold fingers"

As proposed, Note 2 to Category XII(c) identifies certain Defense Articles that would become eligible for export under the EAR when integrated with end-items subject to the EAR. However, as standalone articles they would remain subject to the ITAR.

> The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), and (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable.

While this 'Note" includes, as part of the exception from the See Through rule (*e.g.*, certain image intensifier tubes, photon detectors, various types of focal plane arrays, infrared focal plane arrays and certain infrared imaging camera cores) IDCAs with cryocoolers as described in paragraph (c)(9) are excluded from the Note. The text of paragraph (c)(9) follows:

> (c)(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:
>
> (i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;
>
> (ii) Active cold fingers;
>
> (iii) Variable or dual aperture mechanisms; or
>
> (iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category

Proposed revision: Note 2 to Category XII(c) should be expanded to include the articles in paragraph (c)(9) as follows:

> The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), ~~and~~ **(c)(9) and** (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR […] item inoperable.

Justification:

- We are not aware of publicly available information confirming that unauthorized diversions of cryocoolers have occurred resulting from their extraction from commercial/dual-use equipment. If there is such information and it is not within the public domain, then the appropriate U.S. Government agencies should initiate discussions with the U.S. domestic industry and Wassenaar member states to address this issue.

- The net effect of the exclusion of paragraph (c)(9) from Note 2 is to impose ITAR export and reexport controls on all commercial equipment that incorporate a cooled IDCA. Although there are limited exceptions (approximately one percent of sales), for all intent and purpose, as ITAR-controlled end-items U.S.-origin cooled commercial equipment that incorporate IDCAs with the temperature ranges provided by cryocoolers identified in paragraph (c)(9) could not compete in the commercial marketplace with equipment from non-U.S. sources.

  In addition to ITAR-based limitations on reexports, based on the proposed standard in Note 2, it would not be possible for the IDCA OEM, or for the manufacturer of the cooler, to repair and replace elements within the IDCA. Generally, under the proposed ITAR standard, attempts to repair an IDCA would render the cooler inoperable.

B. The Mean-time-to-failure ("MTTF") for controlled cryocoolers should be increased to 10,000 hours.

Ricor has prepared a table identifying the performance characteristics of its principal coolers that is available on the Company's website and that also posts datasheets for its cryocoolers.

Proposed Revision: Based on the MTTF for its cryocoolers, and a review of the data sheets and brochures available from other manufacturers, we believe that the MTTF should be increased to 10,000 hours. As such, paragraph (c)(9) would appear as follows:

> (c)(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:
>
> (i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of ~~3000~~ **10,000** hours; [. . .] of this category.

In addition, ECCN 6A002.d should be revised reflect the exclusion of certain cryocoolers from ITAR control.

Justification:

- The proposed paragraph (c)(9) with an MTTF in excess of 3,000 hour is a standard so low and encompassing that it would apply to virtually all cryocoolers sold for commercial or dual-use applications. Based on our understanding of the requirements of commercial and military customers, we believe that an increase of the MTTF to 10,000 hours should permit such cryocoolers with an MTTF under 10,000 hours to be exportable under the EAR.

- In our experience, military end-users require a higher MTTF than commercial customers and are willing to invest in cryocoolers with a higher cost margin (*i.e.*, ranging from 25 to 40 percent) in order to achieve a MTTF (*e.g.*, 15,000 to 30,000 hours and possibly even greater). Because of the significantly higher cost of military equipment over commercial products incorporating IDCAs with cryocoolers, there is value and enhanced reliability for military systems to incorporate components with an MTTF exceeding 10,000 hours.

- Adoption of the proposed MTTF revised standard would support the export of dual-use cryocoolers in commercial equipment. Accordingly, exports of cryocoolers below an MTTF of 10,000 hours would classified in ECCN 6A002. This ECCN is subject to National Security Column 2 ("NS/2") controls. In parallel, technology for the development of equipment, materials or software in ECCN 6A002 is subject to NS/1 controls. Further, ECCN 6E002 applies NS/1 and UN controls to technology for the production of equipment controlled by 6A002.

- If it is deemed necessary to strengthen EAR controls on exports of cryocoolers, one alternative would be to require licensing to all countries, except Canada (*i.e.*, NS/1 controls). Other adjustments to the controls on cryocoolers could be applied regarding sales to a "military end-user" or for incorporation into a "military commodity." These and other options should be part of the public review process inherent in the Export Control Reform initiative.

- While Ricor continues to believe that the EAR currently provides sufficient controls regarding the export of cryocooler technology, comparable levels of control under the ITAR are set forth in **Note 1 to paragraph (f)** regarding Technical Data and Defense Services related to "integrated IRFPA IDCAs controlled in paragraph (c)(9). Further **Note 2 to paragraph (f)** applies specific controls on Software and Technical Data related to design or manufacturing process descriptions. Finally, **Note 2 to Paragraph A of Note 2 to paragraph (f)** clarifies the extent to which technical information can accompany an approved commercial export.

    - Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, *provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.* (Emphasis added.)

    - Ricor regards the "design methodology," "engineering analysis" and "manufacturing know-how" (as these terms are defined within the ITAR) as highly propriety and the principal content of its intellectual property. Moreover, company proprietary manufacturing techniques, developed over years of trial and error, are not easily transferred and Ricor has no interest in releasing such manufacturing know-how. In designing, developing and manufacturing cryocoolers, we believe that it is virtually impossible to reverse engineer modern cryocoolers. Therefore, we respectfully suggest, that domestic and multilateral export controls focus on determining the most efficient and effective manner to regulate the export of cryocooler technology as opposed to anti-tampering measures to prevent the unauthorized diversion of cryocoolers.

- The proposed regulation issued by BIS on 5 May 2015 does not revise the current version of ECCN 6A002.d. While the proposed ITAR controls take precedence over the EAR, ECCN 6A002.d would continue to control a limited number of cryocoolers based on preexisting, and perhaps prospective Commodity Jurisdiction ("CJ") determinations. However, ECCN 6A002 and revised USML XII would likely give rise to overlapping jurisdictions, confusing exporters and eroding the "bright line" between the EAR and ITAR that was a principal objective of Export Control Reform.

- Therefore, ECCN 6A002.d.2 should be revised as follows to control cryocoolers that are not subject to ITAR controls. as follows:

  6A002 Optical sensors and equipment, and "components" therefor, as follows).

  d. Special support "components" for optical sensors, as follows:

  d.1. "Space-qualified" cryocoolers;

  d.2. Non-"space-qualified" cryocoolers having a cooling source temperature below 218K (-55° C), as follows:

  d.2.a. Closed cycle type with a specified Mean-Time-To-Failure (MTTF) ~~or Mean-Time-Between-Failures (MTBF), exceeding 2,500~~ **under 10,000** hours; [. . .]

The proposed regulation issued by BIS on 5 May 2015 does not revise the current version of ECCN 6A002.d. While the proposed ITAR controls take precedence over the EAR, ECCN 6A002.d would continue to control a limited number of cryocoolers based on preexisting, and perhaps prospective, Commodity Jurisdiction ("CJ") determinations.

C. The proposed regulation should remove "active cold fingers from Paragraph (c)(9).

We do not understand the term "active cold fingers" as it appear in proposed USML XII(c)(9)(ii). While we understand fully the design, development, manufacture and utility of "cold fingers," the term "active" is not utilized among cryocooler manufacturers. Further, we could not identify this term in published scientific or technical articles.

As a term without definition, the current reference to "active cold fingers" could be interpreted to include all cold fingers, when in fact cold fingers are mechanical and passive parts designed for each cryocooler model to "minimize the thermal conductivity between the cooled mass and the outside world" and are usually constructed of stainless steel, inconel and titanium.[1]

Therefore, we recommend deletion of this term for the following reasons.

- Cold fingers are generally made in a facility with machining capabilities. While they are designed to function with cryocoolers, they are not necessarily sourced from the cryocooler manufacturer. Moreover, as a machined part, their design does not incorporate any special manufacturing. Therefore, we do not understand why ITAR controls would be applied to cold fingers.

- If the term "active cold fingers" is intended to describe a a narrow and specific type of cold finger that warrants control in paragraph (c)(9), its definition should be incorporated directly into paragraphs (c)(9)(ii) and (e)(7).

- If a special type of "active" cold finger is subject to controls in (c)(9) and (e)(7), a new Note should clarify that the controls in these paragraphs do *not* apply to "mechanical" or "passive" cold fingers of the type that are integrated with the class of cryocoolers that were within the scope of ECCN 6A002.d.2. It's a mechanical part sometimes sold separately and other times it is purchased by the cryocooler for from various sources and it's a part a mechanical part made by any machine company   not high tech item

D. The language in Note 2 to Category XII(c) regarding removal "without destruction or damage to the article or render the item inoperable" should be revised and clarified to permit the IDCA OEM and the cryocooler OEM to repair and maintain the "Integrated dewar cooler assemblies (IDCAs)" with cryocoolers."

Proposed Revision:

> The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), ~~and~~ **(c)(9) and** (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and **satisfy an anti-tamper standard such that, except for the**

[1] "What is an Integrated Detector Assembly?" Aron Traylor. College of Optical Sciences, The University of Arizona. (November 29, 2010).

Original Equipment Manufacturers (OEMs) of the components referenced in this paragraph, the articles cannot be removed **by other parties** without destruction or damage to the article**; thus rendering the items subject to the EAR** ~~or render the item~~ inoperable **(*i.e.*, cannot function until a repaired or replacement unit is reinstalled)**.

- In addition, the revised **Note** should clarify that the anti-tamper requirement regarding "destruction or damage" will be implemented at a date to be determined following consultations with the U.S. suppliers and the governments of foreign suppliers in Wassenaar member states of the articles identified in Note 2 to Paragraph (c).

- In the absence of dispositive guidance as to what constitutes the inability to remove a cryocooler "without destruction or damage to the article," the current language imposes a standard that creates substantial risk for exporters. What may be regarded as satisfying this standard by an OEM, may not be acceptable to DDTC or DoD. Therefore, exporters would likely seek advisory opinions requiring detailed technical analysis and testing by U.S. Government laboratories. The proposed standard lacks substance and could result in considerable delays in obtaining export licenses from DDTC.

Justification:

- With the addition of (c)(9), Note 2 would permit an end-item[2] with an IDCA and controlled cryocooler to be regarded for the purposes of export and reexport as subject to the EAR notwithstanding the incorporation of ITAR-controlled Defense Article(s). We acknowledge that this is an exception to the ITAR "See-Through" rule under which the incorporation of ITAR-controlled Defense Articles into a commercial item would subject the commercial item to ITAR-controls. However, for the following reasons this "exception" or "carve out" appears to have limited utility for U.S. exporters.

- Under the proposed Note 2, with respect to commercial equipment that incorporates an IDCA with a controlled cryocooler, if the commercial equipment were not functioning according to its performance specifications, the IDCA could not be repaired; *e.g.,* the cryocooler could be serviced or replaced. In other words, replacing the IDCA and cryocooler as one unit would be the only, and uneconomic, alternative.

    - Relative to the cost of commercial equipment, such as for gas detection, furnace inspections and conductivity testing, the cost of replacing the IDCA in commercial equipment is significant relative to the cost of replacing the cryocooler. In general, the cost of the

[2] ITAR § 120.45(a) defines an "end-item" as "a system, equipment, or an assembled article ready for its intended use. Only ammunition or fuel or other energy source is required to place it in an operating state."

cryocooler is roughly approximately 20 percent of the cost of the IDCA.

- If foreign-made equipment incorporating IDCAs of the type identified in (c)(9) cannot be serviced and repaired by OEMs, why would customers outside the United States purchase U.S.-origin equipment when its long-term operating cost beyond warranty protection would be significantly higher than a foreign-made alternative?

- The proposed revision would permit the IDCA OEM and the cryocooler OEM to repair and maintain the “Integrated IRFPA dewar cooler assemblies (IDCAs)” with cryocoolers” and “active cold fingers.”
- As an additional complication, under the proposed rule, if a defective U.S.-origin IDCA were to be returned for repair from abroad, it would be imported temporarily into the United States as an ITAR article. Accordingly, it would be eligible for the Temporary Import License Exemption at ITAR § 123.4(a)(1) for servicing “*e.g.,* inspection, testing, calibration or repair, including overhaul, reconditioning and one-to-one replacement of any defective items, parts or components. . . ” Only U.S. persons, or foreign persons authorized under an ITAR foreign person employment license, could access the IDCA.

- Ricor is developing a “one-time cooler” for certain commercial applications, *e.g.,* for use in the detection of toxic or flammable gases. The intent of this design is such that removal of the cooler would prevent it from being serviced, repaired or reintegrated with another detector. A party not authorized to procure or acquire commercial equipment with a component identified in paragraph (e)(7), would *not* be able to extract and repurpose the cooler. In addition, there would be a high risk of damage or destruction to the IDCA. Ricor is prepared to review its “one-time cooler” with representative of agencies that administer export controls.

E. The scope of proposed USML XII(e)(7) and the Note to paragraph (e) require clarification.

Paragraph (e)(7) repeats the text of cryocoolers and active cold fingers that appear in paragraph (c)(9). While the later paragraph imposes ITAR controls on IDCAs that incorporate cryocoolers, the Note to paragraph (e) states clearly that the listed parts and components are subject to the EAR when they are “integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article. . . ”

As we understand this Note, while the items in paragraph (e)(7)(i) and (ii) are subject to ITAR controls as individual items, they could theoretically be incorporated directly into subcomponents, subsystems or end-items subject to the EAR. However, if incorporated into an IDCA, they would, in effect, be subject to the ITAR since the IDCA is ITAR-controlled by virtue of paragraph (c)(9). While this may provide some limited opportunity for the export of the cryocoolers and cold fingers listed in paragraph (e)(7), it is our experience that virtually all cryocoolers are incorporated in IDCAs. If this interpretation is correct, then the Note would have a small effect on releasing a very small number of cryocoolers from ITAR licensing controls.

While we have proposed specific revisions to paragraph (c)(9) and (e)(7) and their related Notes, we believe that cryocoolers should continue to be classified within ECCN 6A002. Alternatively, cryocoolers (and their parts) should be divided between the EAR and the ITAR as suggested above based on their MTTF.

III. General Comments on the Proposed Transfer of Export Jurisdiction of Cryocoolers from the EAR to the ITAR

A. The proposed rules will adversely affect U.S. industry competitiveness, including manufacturers of cryocoolers and "active cold fingers."

With the context of Export Control Reform, neither DDTC nor BIS have published documentation to demonstrate that there has been an ongoing diversion of cryocoolers or active cold fingers to countries with policies inimical to the national security or foreign policy interests of the United States. With all due respect, the change in jurisdiction for cryocoolers from EAR to ITAR controls, and the accompanying controls on Technical Data and Defense Services, constitute a U.S. unilateral control that will accelerate the decline in the competitiveness of the U.S. industry. This decline has been documented in reports issued by BIS[3], private sector industry studies[4] and the U.S. trade press. The proposed change in export licensing jurisdiction to the ITAR involving cryocoolers and a certain type of cold finger, will likely reduce further the global competitiveness of the U.S. industry. A study published in 2013 by The Eisenhower School,[5] ("the Eisenhower Study" or "Study") in our view, correctly describes the state of the U.S. industry and the as yet unrealized benefits of Export Control Reform. Based in part on the BIS study published in October 2012, the Eisenhower Study states: "Currently the US is the largest exporter of thermal imaging devices; however, US global market share has been on a steady decline since 2002."

The following excerpts provide an optimistic projection that the Export Control Reform Initiative ("ECRI") would simplify controls, enhance the competitiveness of the U.S. industry, and thereby facilitate future technical and cost benefits for the U.S. military. According to the Study, export controls under the ITAR and EAR

[3] "Defense Industrial Base Assessment of the U.S. Imaging and Sensor Industry." U.S. Department of Commerce, Bureau of Industry and Security. Office of Strategic Industries and Economic Security. (October 2006).

"Critical Technology Assessment – Night Vision Focal Plane Arrays, Sensors and Cameras." U.S. Department of Commerce, Bureau of Industry and Security. Office of Technology Evaluation (October 2012).

[4] Maxtech International, Inc. "The World Market for Commercial and Dual-Use Infrared Imaging and Infrared Thermometry Equipment. (Vol. IRW-C, 2014 Edition.)

[5] "Spring 2013 Industry Study. Final Report – Weapons Industry." The Dwight D. Eisenhower School for National Security and Resource Strategy. National Defense University. Fort McNair, Washington, DC. (*See* pages 8-10, footnotes deleted.)

> have made it more difficult for US firms to remain competitive in the global market, because foreign companies are free to offer competitive products while US firms are restricted. Worldwide there are over 100 non-US competitors in 23 countries that compete with US firms [. . .].
>
> At the present time, thermal imaging devices and systems are adversely affected by several export controls. US firms are hopeful that changes from the Export Control Reform Initiative (ECRI), will help increase their market share overseas, which could replace some of the lost income due to reduced US sales. So far there does not appear to be any significant changes in this area, all while US firms are steadily losing export business, down to 8% market share in 2010 from more than an 18% share in 2002.

With respect to the future of ECRI, the Study recommended supporting ECRI

> and other initiatives to *simplify the export rules and increase US competitiveness*. Many lower resolution thermal imaging technologies are common across the globe, and these compete with US firms. *Export controls should be reduced or even eliminated for those technologies that are prevalent across the global market, allowing US firms to compete openly in the market and increase overall sales, which will assist in reducing overall unit costs across all product lines*. (Emphasis added.)

In contrast to the expectation regarding ECRI in the Study, the application of ITAR controls to formerly commercial products would create substantial disincentives for companies abroad to procure ITAR-controlled cryocoolers. The extent to which these controls are a disincentive to purchasing U.S.-origin, ITAR-controlled cryocoolers and their parts are summarized below.

- Permanent DSP-5 export licenses would be required for the sale of individual cryocoolers and, as such, would not be eligible for an EAR-based *de minimis* calculation. The requirement that they would be destroyed or damaged if removed from an IDCA will increase prices and the lifetime operational costs of individual products. If a foreign customer purchased U.S.-origin cryocoolers, the foreign commercial equipment would become subject to ITAR reexport controls (*i.e.*, DDTC would need to approve in advance each end-user). Moreover, it appears most unlikely that DDTC would approve Distribution Agreements for cryocoolers.

- The temporary import and temporary export of cryocoolers would be subject to DSP-61 and DSP-73 license controls. U.S.-origin commercial end-items could be entered for repair under an exemption, but the anti-tamper requirements as proposed would forestall the servicing and repair of the cryocoolers.

- Technical cooperation between a U.S. and a foreign company involving cryocooler Technical Data would require a DSP-5 or a Technical Assistance Agreement. In either event the foreign company should assume that its use of ITAR-controlled Technical Data would render its cryocoolers subject to ITAR jurisdiction and related licensing controls. If a foreign company imported a U.S.-origin cryocooler for a commercial application, and its employees were not covered by a security clearance issued by their national government, the company would need to screen its employees for substantive contacts with U.S. embargoed countries and have its employees sign ITAR-based Non-Disclosure Agreements.

- Finally, ITAR § 129.4(a)(2)(vi) would require that "brokers" selling ITAR-controlled cryocoolers obtain advance approval from DDTC in the form of a brokering license.

Individually or in combination, such ITAR controls applied unilaterally by the United States would likely contribute further to the U.S. share of global market for cryocoolers, thus shifting cryocooler R&D and related applications offshore.

B. The proposed revision of USML XII is a unilateral control that circumvents the Wassenaar process for establishing controls on dual-use and military products.

There is an alternative to unilateral controls on cryocoolers. While there is established foreign availability for cryocoolers, with the exception of the People's Republic of China, the other non-U.S. cryocooler manufacturers known to Ricor are located in Wassenaar member states: Canada, France, Germany, Japan, Slovenia, South Korea and Israel (although not a member of the WA , Israel has implemented the WA dual-use list in its domestic export control regulations). Therefore, Ricor respectfully suggests that before the imposition of U.S. unilateral controls, the United States should seek to establish within Wassenaar a common export rule regarding IDCAs with cryocoolers. .

The applicable text in the Wassenaar Arrangement for dual-use controls that follows is the basis for ECCN 6A002.d

> 6. A. 2. d. Special support components for optical sensors, as follows:
>
> 1. "Space-qualified" cryocoolers;
>
> 2. Non-"space-qualified" cryocoolers having a cooling source temperature below 218 K (-55°C), as follows:
>
> a. Closed cycle type with a specified Mean-Time-To-Failure (MTTF) or Mean-Time-Between-Failures (MTBF), exceeding 2,500 hours;

Under WA-Munitions List ("ML"), Note 1 in ML15 applies controls to "Cooling systems for imaging systems" provided they are "specially designed for military use." The clear implication is that cooling systems designed for other than a military application were not intended to be controlled as munitions items. The adoption of "specially designed" as a control and decontrol criteria is absent from paragraph (c)(9). The incorporation of the term "specially designed" in (c)(9) would provide the basis for applying a high level of licensing controls and interagency review to proposed exports of cryocoolers sold exclusively for military applications. With the demise of the Militarily Critical Technologies List ("MCTL"), there is no objective standard to determine whether the export of individual products, based on a U.S. technological advantage, should be strictly controlled. These circumstances underscore the utility of reviewing controls on cryocoolers within Wassenaar.

C. There is significant foreign availability of cryocoolers and their related parts and components (*e.g.*, cold fingers). Accordingly, foreign availability should be a major factor in determining export jurisdiction for cryocoolers.

Accordingly, those interested in purchasing cryocoolers and avoiding robust U.S. defense export controls may simply source their desired cryocooler from a variety of foreign vendors. By way of examples, such cryocoolers can be purchased from Thales Cryogenics in France, from Le-tehnika in Slovenia and, as noted above, from companies in other Wassenaar member states and the PRC. Attached to this submission are examples of cryocoolers available from non-U.S. sources as dual-use items. This attachment does not include specification and data sheets from all known manufacturers. Such an effort would constitute a full-blown foreign availability study. However, upon request Ricor is willing to provide additional information regarding foreign availability. We know that laboratories, factories and other facilities interested in ongoing monitoring of potentially hazardous gases often install sensor-based monitoring systems that contain embedded cryocoolers.

- One such examples is the Airgard® product offered for sale by MKS Instruments, Inc., a NASDAQ traded U.S. company, that offers process control solutions for manufacturing industries.

- Other examples of such products include Flir's GF306, Microptik BV's SF6 Finder MTG 80 (produced by a company in the Netherlands), and amperis's SF6 Detection TC706 product (produced by a company in Spain), each of which functions to detect sulfur hexafluoride and other harmful gases and for detecting gas leaks.

- An additional non-defense or aerospace system in which cryocoolers are embedded includes conductivity testing equipment, such as the thermal conductivity tool, "C-Therm Tci", offered by C-Therm Technologies.

- Other civilian systems include heat-sourcing sensing systems such as the TE Cooled SCD-13 Detectors offered by CalSensors and germanium-sensing equipment such as ORTEC's Micro-Detective-HX and similar products offered by Areva group's Canbera company.

Brochures for these companies and their cooled products, as well as for other companies (*e.g.*, K.I.P. in the PRC) are attached to this submission.

The U.S. regulations applicable to cryocoolers should be part of a level playing field that includes other companies in other Wassenaar countries and countries that follow WA controls. If DDTC and BIS decide to impose country-specific controls on the export of cryocoolers and their related technology, there are precedents for such a decision that would not disadvantage the entire U.S. industry.

Based on publicly available data, and our own corporate experience, cryocoolers are becoming increasingly prevalent in civilian/commercial products. Aside from the potential negative impact on the availability of advanced U.S.-origin products for military applications, the proposed ITAR rules do not take into account foreign availability and risk disproportionately hindering the development of commercial equipment that utilize IDCAs and thereby cryocoolers.

* * *

In order to facilitate the regulatory review process, Ricor would welcome the opportunity to prove additional information regarding its understanding of the international market for cryocoolers or to discuss related technical issues.

Respectfully submitted,

Frank Perry
Chief Executive Officer
Ricor USA Inc.

Shlomo Baruch
Vice President Quality Assurance, Compliance & Regulations
Ricor Cryogenic & Vacuum Systems Ltd.

Attachments

Attachment 1: Product Brochures for Cooled Products

Infrared camera for SF6 Gas Detection TC706

The TC706 visualizes and pinpoints gas leaks of SF_6, without the need to de-energize high-voltage equipment or shut down the operation. The portable camera also greatly improves operator safety, by detecting emissions at a safe distance, and helps to protect the environment by tracing leaks of environmentally harmful gase.

SF_6 is used in the electric power industry as an insulator and quenching medium for gas-insulates substatios and circuit breakers.

TC706 – Great choice for Gas Leaks Detection

Could detect following gases:

- SF_6
- Chlorine dioxide
- Ethylene
- Ammonia
- Acetic acid
- MEK
- Cyanoacrylate
- FREON-12

TC706 Unique Feature:

- Adapt passive thermal imaging technology, could accurately find the leakage point at long distance without power supply shutdown
- Using Cooled QWIP detector, enjoy superior image quality and accurate temperature measurement
- Voice and video recording function
- HD OLED view finder, combined with 5" touch rotating screen, suitable for many on-site using
- No specific background and auxiliary light needed, suitable for many on-site checking
- Small size, light weight and easy operation, suitable for single person on-site using

Technical parameters

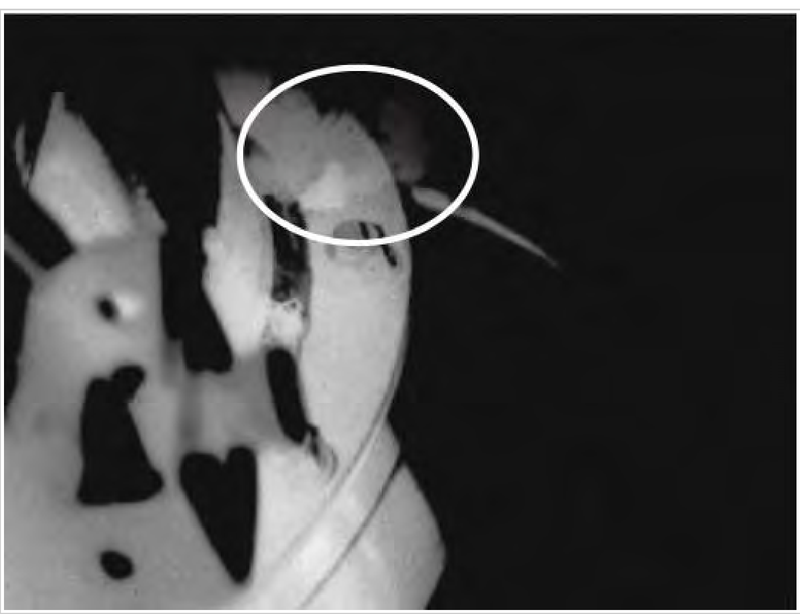
Specifications		TC706
Detector characteristics	Detector type	Cooled QWIP
	Array size/format	320×256
	Field of view/min focus distance	14,5°×10,8°/0,5m or 24°x18°/0,3m
	Spatial resolutions(IFOV)	0,79mrad or 1,13mrad
	NETD	[illegible]

Image manage	NETD		≤0,025℃@30℃
	Frame rate		60Hz
	Focus		Auto / Manual / Motorize
	Zoom		1-4x electronic zoom
	Spectral range		9,8 – 11,2µm – peak 10,55µm
	CCD		1,3 million CMOS
Image display	View finder		HD 0,6" color OLED, with zoom
	LCD		HD 5" color digital touch screen, 800x600
Measurement	Temperature ranges		-40℃～+500℃
	Accuracy		±2℃ or ±2% of reading, whichever is greater
	Measurement correction		Auto/Manual
	Mode		Up to 10 movable spots. Up to 5 movable areas (maximum, minimum and average temperatures). Up to 2 movable lines. Line profile. Isotherm. Temperature difference. Alarm (voice, color)
	Image control	Color pallete	11 pallettes changeable (Iron, Rainbow, Grey and Grey inverted, etc)
		Image adjustment	Auto/Manual adjustment of contrast and brightness
	Setup		Date/time, temperature unit °C/°K/F, language
	Emissivity correction		Variable from 0.01 to 1.0
	Background temp adjustment		Auto, according to the background temp
	Atmospheric transmission correction		Automatic correction according to user input object distance, humidity and temperature
Image Save	Storage Card		8G SD card, storage > 6000
	Storage Mode		Manual/automatic single-frame image storage, continuous visible, infrared video recording
	IR image	Single frame	JPEG, 14 bit thermal image with measurement data
		Video	MPEG-4 or 14 bit thermal image with measurement data
	Visual image	Single frame	JPEG
		Video	MPEG-4
	Voice annotation		40s., saved together with the image
	Image improvement		Averaging (S2, S4, S8, S16), spatial filter
Laser pointer	Power supply		Second level, 1mW/635nm(red)

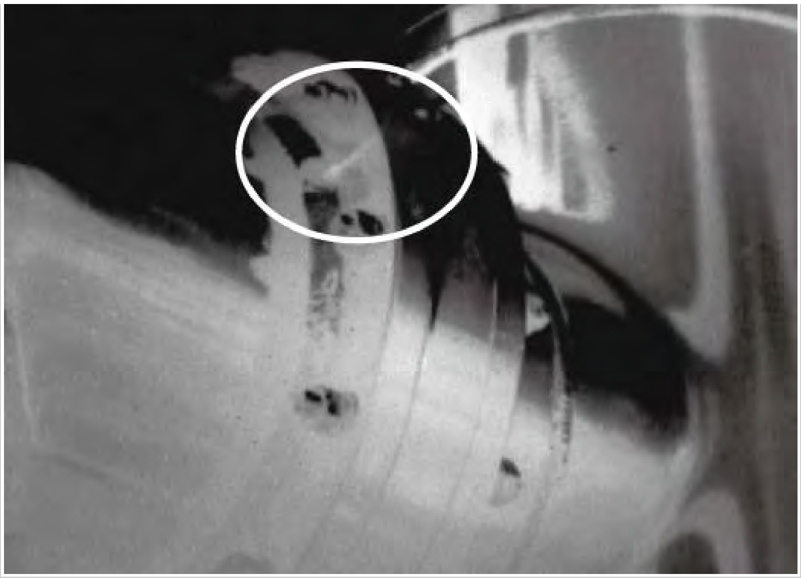
Laser pointer	Power supply	Second level, 1mW/635nm(red)
Power supply	Battery type	Li-Ion, rechargeable
	Battery operating time	3 hours continuous operation
	Charging system	Intelligent charger or power supply adaptor online charge
Power system	Power saving	Yes
	External power	10 – 15 V DC
Environment	Working temp	-15 ℃ - +50 ℃
	Humidity	≤ 90% non-condensing
	Encapsulation	IP54
Physical characteristics	Weight	3 Kg
	Dimension	335x160x172mm
Interface	External DC Input	Yes
	Audio output	Yes
	Video output	HDMI
	USB 2.0	Image, measurement data and voice transfer to PC

Download software

Using Infrared camera for SF6 Gas Detection TC706



Leak detection Infrared camera for SF6 Gas Detection TC706



Example image leak detection Infrared camera for SF6 Gas Detection TC706

Hand shank and view finder could rotate simultaneously

Hand shank and view finder could rotate simultaneously, easy for observation

Infrared camera for SF6 Gas Detection TC706

Do you want to buy high quality Professional thermographic infrared cameras?

Inquire for our **Professional thermographic infrared cameras prices.**

Do not hesitate to **contact us**, call us today by phone **(+34) 982 20 99 20.**

We are happy to help you.

TC706

HIGHEST RESOLUTION AND ACCURACY
WITH LOW COST

SF_6 Gas Detection

TC706

Could detect following gases:

* SF_6
* Ammonia
* Cyanoacrylate
* Chlorine dioxide
* Acetic acid
* FREON-12
* Ethylene
* MEK

amperis

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info@amperis.com | www.amperis.com

The TC706 visualizes and pinpoints gas leaks of SF_6, without the need to de-energize high-voltage equipment or shut down the operation. The portable camera also greatly improves operator safety, by detecting emissions at a safe distance, and helps to protect the environment by tracing leaks of environmentally harmful gase.

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Hand shank and view finder could rotate simultaneously, easy for observation

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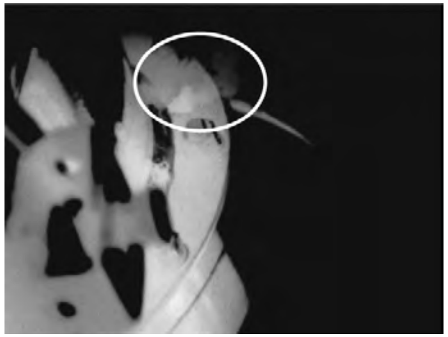
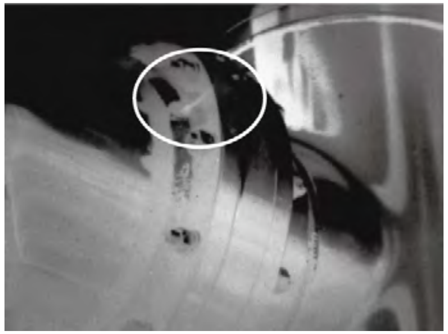
- No specific background and auxiliary light needed, suitable for many on-site checking.
- Small size, light weight and easy operation, suitable for single person on-site using.





Examples of leak detection

AMPERIS PRODUCTS S.L
Agricultura,34
27003, Lugo, Spain

Contact

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info@amperis.com | www.amperis.com

Technical parameters TC706			
Detector characteristics	Detector type		Cooled QWIP
	Array size/format		320×256
Image manage	Field of view/min focus distance		14,5°×10,8°/0,5m or 24°x18°/0,3m
	Spatial resolutions(IFOV)		0,79mrad or 1,13mrad
	NETD		≤0,025℃@30℃
	Frame rate		60Hz
	Focus		Auto / Manual / Motorize
	Zoom		1-4x electronic zoom
	Spectral range		9,8 – 11,2µm – peak 10,55µm
	CCD		1,3 million CMOS
Image display	View finder		HD 0,6” color OLED, with zoom
	LCD		HD 5” color digital touch screen, 800x600
Measurement	Temperature ranges		-40℃～+500℃
	Accuracy		±2℃ or ±2% of reading, whichever is greater
	Measurement correction		Auto/Manual
	Mode		Up to 10 movable spots. Up to 5 movable areas (maximum, minimum and average temperatures). Up to 2 movable lines. Line profile. Isotherm. Temperature difference. Alarm (voice, color)
	Image control	Color pallete	11 pallettes changeable (Iron, Rainbow, Grey and Grey inverted, etc)
		Image adjustment	Auto/Manual adjustment of contrast and brightness
	Setup		Date/time, temperature unit °C/°K/F, language
	Emissivity correction		Variable from 0.01 to 1.0
	Background temp adjustment		Auto, according to the background temp
	Atmospheric transmission correction		Automatic correction according to user input object distance, humidity and temperature
Image Save	Storage Card		8G SD card, storage > 6000
	Storage Mode		Manual/automatic single-frame image storage, continuous visible, infrared video recording
	IR image	Single frame	JPEG, 14 bit thermal image with measurement data
		Video	MPEG-4 or 14 bit thermal image with measurement data
	Visual image	Single frame	JPEG
		Video	MPEG-4
	Voice annotation		40s., saved together with the image
	Image improvement		Averaging (S2, S4, S8, S16), spatial filter
Laser pointer	Power supply		Second level, 1mW/635nm(red)

Power supply	Battery type	Li-Ion, rechargeable
	Battery operating time	3 hours continuous operation
	Charging system	Intelligent charger or power supply adaptor online charge
Power system	Power saving	Yes
	External power	10 – 15 V DC
Environment	Working temp	-15 ℃ - +50 ℃
	Humidity	≤ 90% non-condensing
	Encapsulation	IP54
Physical characteristics	Weight	3 Kg
	Dimension	335x160x172mm
Interface	External DC Input	Yes
	Audio output	Yes
	Video output	HDMI
	USB 2.0	Image, measurement data and voice transfer to PC

The Micro-Detective-HX

The ORTEC Micro-Detective-HX is the most advanced hand held radioisotope identifier (RID) commercially available.

Path: Home > Products-Solutions > Hand-Held Radioisotope Identifiers - Micro-Detective-HX

Nuclear Security and Safeguards

- Overview
- Spectroscopic Portal Monitoring Systems
- Hand-Held Radioisotope Identifiers - RIIDS
- Mobile, Transportable Detection Systems
- Neutron / Fission Systems
- Chemical Weapons Identification
- Nuclear Safeguards

Hand-Held Radioisotope Identifiers

- Micro-Detective-HX
- Micro-Detective
- Detective-100T
- Accessories
- HPGe Advantage
- Library

Micro-Detective-HX

Advanced Hand-Held Radiation Detection and Identification RIID

The "-HX" is the commercial embodiment of additional development carried out under contract between AMETEK and the U.S. Department of Homeland Security.

- Wireless Remote Monitoring - Remotely control and monitor from a central location
- Portable - Light weight, long battery life, "one-hand" operation with GPS location
- Simple to Operate - Touchscreen or push button with audible and visual alarm indicators
- Rugged - High or low temperatures, water proof, dust proof and drop hardened
- Superior Algorithms - Low false alarm rates, more than 150 nuclide IDs and superior SNM search
- Gamma and Neutron Detection - Identification, dose rate and count rate
- Detects and Identifies x-rays and gamma rays in any form (solid, liquid, or gas)
- Auto Calibration - Continuous real-time detector stabilization
- Detective-Remote Compatible - Use as a mobile, transportable or choke point monitor

Read more about the ORTEC Micro-Detective-HX

Micro-Detective/Micro-trans-SPEC Battery Upgrade

ORTEC®

Micro-Detective-HX

Enhanced Capability, Ultra-Light, High-Fidelity
Hand-Held Radioisotope Identifier

AMETEK®
ADVANCED MEASUREMENT TECHNOLOGY

Micro-Detective-HX

- Wireless Remote Monitoring – Remotely control and monitor from a central location.
- Portable – Light weight, long battery life, "one-hand" operation with GPS location.
- Simple to Operate – Touchscreen or push button with audible and visual alarm indicators.
- Rugged – High or low temperatures, water proof, dust proof and drop hardened.
- Superior Algorithms – Low false alarm rates, more than 150 nuclide IDs and superior SNM search.
- Gamma and Neutron Detection – Identification, dose rate and count rate.
- Detects and Identifies x-rays and gamma rays from radioactive sources in any form (solid, liquid, or gas)
- Auto Calibration – Continuous real-time detector stabilization.
- Detective-Remote Compatible – Use as a mobile, transportable or choke point monitor.

Micro-Detective-HX is the latest development of high purity germanium (HPGe) based hand-held radioisotope identifiers "RID"s. The "-HX" is a commercially available version hand-held that includes additional features carried out under contract with the U.S. Department of Homeland Security.[1]

The Micro-Detective-HX Features

- 40% lighter than industry-leading ORTEC Detective-EX.
- 50% reduction in overall size.
- Simple to operate: Bright, clear, SUNLIGHT READABLE display, touch sensitive screen, and intuitive menus.
- Rugged: Enclosure, display, and all perforations are sealed against moisture and dust.
- Built in neutron detector.
- Built in GPS.
- Removable data storage SD card.
- WiFi 802.11 wireless communications.
- Wireless Mobile MCB Server software.

Plus the latest improvements

- Operating time of up to 5 hours on a single battery.
- "Snap-open" battery door for rapid battery exchange with minimal down-time.
- New improved, silent running, low-power cryo-cooler.

[1]The contract was awarded by the U.S. Department of Homeland Security (DHS) Domestic Nuclear Detection Office (DNDO) under the Human Portable Radiation Detection System (HPRDS). The HPRDS program began in 2006 in order to develop next-generation hand-held devices that would bring faster and more reliable means to detecting and identifying radioactive materials. Of the five contractors initially chosen to improve and enhance their radiation identification technology, AMETEK recently was selected by DHS to continue in the HPRDS program.

Micro-Detective-HX

Hardware

The Micro-Detective-HX features compact, light weight and rugged hardware. A 50 mm diameter HPGe crystal in a “hardened” cryostat is cooled by an integrated low-power Stirling-cycle cryo-cooler. The latest version Micro-Detective-HX features a new cooler, offering reduced levels of accoustic noise and vibration, and longer operation life. The hardened cryostat is entirely free of conventional molecular sieve, allowing the instrument to be turned off or on at any point in the detector cool down or warm up cycle without risk. This is impossible with conventional HPGe cryostat systems which require careful temperature cycling procedures to avoid damage.

A built-in digital MCA system and powerful data processor are included. All models feature the same bright and clear VGA resolution display, readable in direct sunlight, with a touch sensitive operator screen. Menu navigation is highly intuitive. The radionuclide gamma-ray spectrum may be displayed and manipulated (e.g., vertical scale, zoom) like a conventional multichannel analyzer.

Gamma and neutron count rate and gamma dose rate are displayed continuously both numerically and in bar graph form.

In the latest version, the Micro-Detective-HX internal battery provides enough power for up to 5 hours of operation and is easily replaced in seconds, allowing continuous in-field operation. At just under 16 lbs. in weight, the Micro-Detective sets a world record for portable, high resolution nuclide identifiers, by a wide margin.

The snap-open battery compartment makes battery changing simple.

Desktop battery charger (MICRO-DET-ACC-CHGR). Recharges battery (MICRO-DET-ACC-BAT) in 4 hours.

Exclusive to the -HX

- One-handed control of instrument through two handle-mounted buttons, or though touchscreen.
- Visual Alarms: LEDs provide clear and simple indication of nuclide type: threat, innocent or suspect, plus error indication.
- Vibrating alarm built into handle.
- 3-level auditory alarms can be routed through headphones.

-HX Software Approach

HPGe is already acknowledged as the “perfect” detector for a radioisotope identifier. It has ~40 times better energy resolution (selectivity) than the nearest alternative. Unlike lower-resolution detector types, HPGe crystals must operate at cryogenic temperatures — an engineering issue ORTEC solved 25 years ago. Several hundred Detective family instruments in the field attest to the reliability of today’s miniature Stirling cycle coolers used for this purpose.

Beyond the intrinsic selectivity of the HPGe detector type, the ultimate performance in terms of its fidelity of identification (zero false positives or false negatives is the goal) depends on the software algorithms. Its practicality in use depends on reliable hardware and a user interface which is easy to learn and interpret.

The Micro-Detective-HX performance has been enhanced with the introduction of the new Detective-Pro user interface. Further reductions in both false positive and false negative results have been achieved, combined with a new design user interface and new modes of operation.

The Detective-Pro User Interface is

- Clear.
- Simple and intuitive.
- Informative.
- Based on simple-to-use hardware, even with one gloved hand.

The Micro-Detective-HX in Use: Overview

From the hardware standpoint the user interface comprises:

- Two buttons on the front of the handle, Navigate (N) and Select (S), with which all survey and sampling operations can be performed.
- A high-resolution, sunlight readable, color touchscreen provides an alternative way to choose menu options and enter data such as passwords and alarm limits.
- Audio-visual feedback:

  Menus are designed to be operated with N and S buttons only, but if preferred, the touchscreen is always available.

  On-screen help messages display radiation and system error alarms. The messages tell the user what the next press of the N and S buttons will do.

  An audio alarm with three volume settings can be used with headphones and a vibration alarm is provided in the handle. Either, both, or neither can be enabled.

  A 4-LED panel is used to further inform the operator of alarm conditions.

  Color coding of the LEDs and screen borders match in order to make the instrument as intuitive as possible: red for threat, yellow for suspect and green for innocent.

  Indicators at the top of the screen show the current dose rate in mrem/hr, the number of spectra that can be stored on the SD card, GPS co-ordinates, the power source (external power or battery), battery time remaining, and the on/off state of the audio and vibration alerts. The storage-space and battery-time-remaining readouts alternate every few seconds.

  When radiation is detected and identified, the identification is posted to the real-time identification area of the screen. This area lists the names of any radioisotopes currently being detected and their classification as a threat (T), suspect (S), or innocent (I). It can also optionally show whether the identification is at high (H) or low (L) confidence.[2]

[2]Note the only suspect alarm in standard sampling mode is "Elevated radiation or beta." This indicates the gamma count rate is higher than can be accounted for based on the peaks in the -HX library. The implication is that either an unexpected nuclide or a beta emitter is present.

Display and Control Buttons.

Press Select to Acknowledge
T:U-232

"Radiation Alarm."

Select: End Background
Navigate: Menus

Contextual Messages Give Function of the "S" and "N" Buttons.

Alarm LED Indicator.

Home
1.18 mrem/h Space: 401866

Indicators at Top of Screen.

Type	Source	Conf
S	Elevated radiation or beta	L
I	Cs-137	H
I	Th-232	H

Real-Time Identification Area.

T	Neutron CR 5.63	H

Press Select to Acknowledge
T:Neutron CR 1.24

Neutron Alarm.

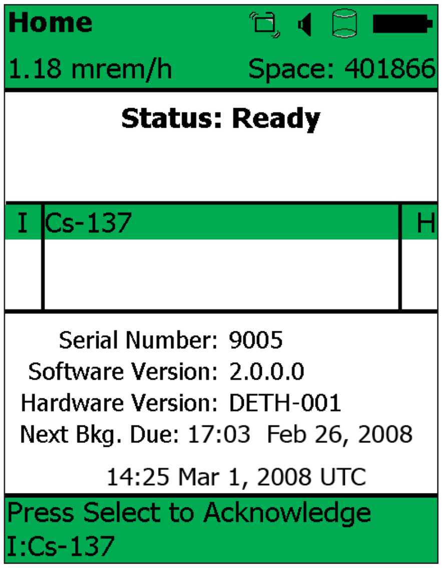
The Micro-Detective-HX in Use: Modes of Operation

How the -HX Collects and Analyzes Data

- A flexible approach to minimize time and maximize effectiveness.
- Continuous running and fixed time modes with "end survey summary."
- Maximum flexibility, maximum sensitivity.
- Adaptable to the chosen CONOPS design.

The -HX monitors for radiation at all times. It collects one spectrum per second, then begins analyzing a rolling window of the eight most recent 1-second spectra for radioisotope identification and alarms.

- "Home" or "Passive Monitor" mode is the simplest form of operation. In this mode, the -HX is continuously "looking," but not storing data.
- In "Detect" or "Survey" mode, the instrument stores the 1-second data slices and attempts to make an ID based on the 8-second rolling windows.
- Optional "Long Samples" or "Fixed Samples," performed during the "Detect" mode survey, add longer spectrum acquisitions to the data stream of 8-second rolling-window analyses.
- The "End Survey Report" is a cumulative analysis of all 1-second data slices in the survey, providing increased detection sensitivity for weak or distant sources.



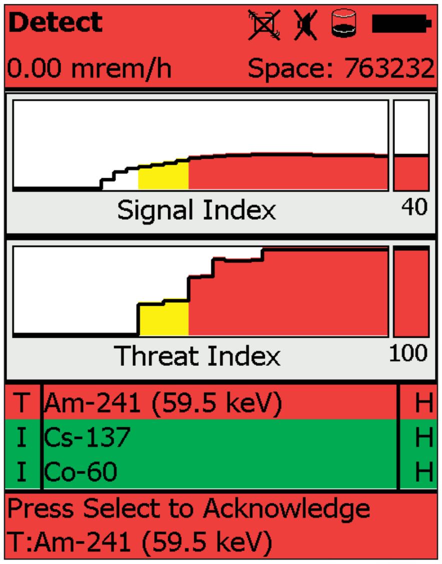
Home (Passive Monitor Mode), Innocent Cs-137 (Green Color Code).

Modes of Operation: Home (Passive Monitor) Mode: "Always Looking"

In Home (Passive Monitor) mode, the instrument is continuously "looking" but not storing data. Gamma dose-rate, battery life, storage space, and GPS co-ordinates are displayed. In this mode, the -HX acts like a survey meter in that if it is moved away from the source, the ID will be removed from the screen. However, any alarm posted persists and must be acknowledged (cleared). Data is gathered and processed in 1-second time slices. The -HX analyzes an 8-second rolling window of these slices and attempts to make an ID. Nuclide IDs are posted to the Real Time ID area.

Modes of Operation: Detect Mode (The Survey Concept)

Detect mode is used to better locate and identify sources. A Survey always begins with a Detect mode measurement, and can include Long and Fixed Sample mode (see below) operations also. The -HX can be set to automatically start a survey immediately after it is removed from charge or a survey may be started manually. 1-second data slices are saved to an ICD1/ICD2 file pair (see specification section) on the removable SD card. As in the Passive Monitor mode, the -HX attempts to make an ID based on an 8-second rolling window. At the upper part of the screen, the color-coded strip chart records Signal Index (cumulative activity of ALL nuclides identified). The chart peaks at the location of greatest activity. The lower chart shows the Threat Material Index similar to the Signal Index, but for threat material only. To the right of each strip chart, a vertical bar and numeric value is used to show the current value of the signal and threat indices. If appropriate to the measurement, alarm IDs are displayed in the Real Time ID area and must be acknowledged.

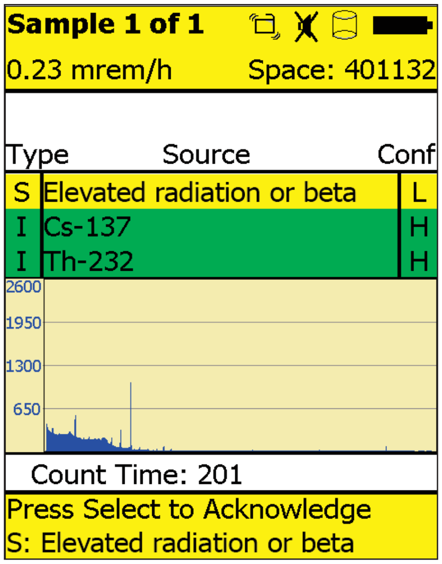


Detect Mode. Threat Am-241 (Red Color Code)

Micro-Detective-HX

Modes of Operation: Long and Fixed Sample Modes

During a Survey, in the Detect mode measurement, a source may have been located and closer scrutiny desired. Long or Fixed Sample modes may be used to achieve this. In Long Sample mode, a single spectrum is acquired for 30 or more seconds and analyzed once per second for alarms. Fixed Samples are treated similarly but have preset durations of 5, 10, 15, 20, 25, 30, 60, 120, or 300 seconds. In Long Sample mode, the live spectral display can be viewed. Long and Fixed Sample spectra and analyses are saved in the ICD1/ICD2 file pair for the Survey, along with the rolling-window and cumulative-analysis data.



Long Sample Mode with Selectable Spectral Display.

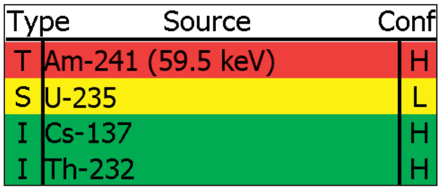
"End Survey Report"

A Survey is started manually or automatically, as described above. Apart from the Detect mode operation, a survey may include either single or multiple long or fixed sample mode measurements. When a Survey is terminated by the operator, an "End Survey" summary report is displayed containing the following:

- Any alarms derived from the 8-second rolling window mode of operation which starts every survey,
- Any alarms derived from an analysis of a cumulative spectrum representing the summation of all the 1-second slices gathered during the survey, thereby attempting to ID any low intensity components which the rolling window analysis might have missed; the cumulative spectrum and analysis data are added to the ICD1/ICD2 file pair for the survey.
- Any alarms derived from those Long and Fixed Sample measurements included in the survey.

Modes of Operation: HX-LCX Operation — For the Expert

The LCX mode is "Low Confidence Expert" mode. This mode is password protected, and displays threat alarms and identifications at an approximately 30% lower confidence level than normal. This results in more "hits" on suspected threat nuclides, and is recommended for use by experienced personnel. Normal mode operation, in contrast, would either not post a threat alarm because the confidence level is too low, or would simply post an elevated radiation or beta alarm rather than listing a specific radionuclide.



LCX Mode Real Time ID Area – Suspect Identification.

The -HX and Background Radiation — No more NORM alarms

The -HX can distinguish between radioactive materials in the environment and the sample, so it does not indicate the presence of activity which is actually due to background. It does this by making periodic background measurements according to a schedule. A user with password access can choose the number of days between required background checks. If the required background update is not performed, the -HX permits unlimited passive monitoring but will not enter Survey Mode. However, even with an expired background, the -HX provides proper, real-time identifications of SNM, RDD, and other threats.

Micro-Detective-HX

The -HX and Digital Stabilization — Making the best of it

Although a digital germanium spectrometer is a highly stable instrument, even with varying temperatures, the -HX is designed for use in conditions that could be considered extreme (which certainly are not recommended but, within the specified mechanical and environmental limits, are not a barrier to correct operation). An automatic gain stabilizer system "locks onto" the natural background K-40 peak (if present) to ensure "perfect" calibration is maintained even in conditions of harsh handling. The stabilizer is "smart." If either the K-40 is determined as being absent, or if a potential gamma-ray interference with the K-40 peak is determined to be present, the stabilizer will be held at a constant setting.

The -HX Nuclide Library

The Micro-Detective-HX has a very comprehensive nuclide list. A subset of the entire nuclide library is the default "Threat Isotopes"; these are marked in RED in the table. The advanced user is able to add any of the nuclides marked in GREEN in Table 1 to the list of red-marked threat isotopes. The color coding in the table shows the default background screen colors and visual alarms the instrument will present when these nuclides are encountered. The YELLOW "suspect" alarm will be posted on the basis of excessive gamma count rate not consistent with the identified nuclides, in other words, either unknown nuclides are present or a beta emitter is present.

Table 1. -HX Nuclide Library.

HEU	Enriched Uranium	U-235	Pu-239	Np-237	U-233
Neutron CR (xx.x cps)	Neutrons Present	U-238	U-232	U-232/Th-232	Am-241
Am-241 (Shielded)	Am-241 (59.5 keV)	Ac-225	Ac-227	Ag-110m	Ar-41
As-72	As-74	At-211	Au-198	Ba-133	Ba-140
Be-7	Bi-207	Bi-212 (Th232/U232 daughter)	Bi-214 (Ra226 daughter)	Br-76	Br-76 (shielded)
Br-76 (heavily shielded)	Br-77	Ca-47	Cd-109	Cd-115	Ce-139
Ce-141	Ce-144	Cf-252/Cf-249	Cm-242	Cm-243	Cm-244
Co-56	Co-56 (shielded)	Co-55	Co-57	Co-58	Co-60
Cr-51	Cs-131	Cs-134	Cs-137	Cu-64	Cu-67/Ga-67
Eu-152	Eu-154	Eu-155	Eu-156	Fe-18	Neutrons on Fe
Fe-59	Elevated radiation or beta emitter	Ga-64	Ga-64 (shielded)	Ga-67	Ga-67 (shielded)
Ge-68/Ga-68	Gd-153	Gd-159	Hf-181	Hg-203	Ho-166m
Ho-166m (shielded)	Ho-166	I-123	I-123 (shielded)	I-124	I-125
I-126	I-126 (shielded)	I-131	I-131 (shielded)	I-132	I-133
I-134	I-135	In-111	Ir-192	Ir-192 (shielded)	Os-194/Ir-194
Ir-194 (shielded)	K-40	Kr-87	Kr-88	Kr-88 (shielded)	La-140
Lu-172	Lu-176	Lu-177	Lu-177m	Mn-52	Mn-54
Mn-56	Mo-99	Na-22	Na-24	Nb-94	Nb-95
Nb-96	Nb-96 (shielded)	Nd-147	Pa-231	Pb-203	Pd-103
Rh-105	Ru-97	Ru-106/Rh-106	Po-210	Pr-144	Ra-223
Ra-226	Ru-103	Sb-124	Sb-124 (shielded)	Sb-125	Sb-127
Sc-46	Se-75	Sm-153	Sm-153 (shielded)	Sn-113	Sr-82/Rb-82
Sr-85	Sr-89	Sr-90/Sr-89/Y-90	Ta-182	Tc-96	Tc-99m
Te-132	Tl-201	Tl-200	Tl-202	Tl-204	Th-229
Th-230	Th-232	Tm-170	Tm-171	W-188/Re-188	Xe-127
Xe-133	Xe-131m	Xe-135	Y-88	Y-91	Yb-169
Zn-65	Zn-62	Zr-95			

Micro-Detective-HX

Micro-Detective-HX Offline Analysis Program

- Views the spectral contents of -HX data files, real time and live time for each spectrum contained in each, radioactive sources identified (if any), and alarm types associated with each identification.
- Reanalyzes the data set with different nuclide libraries (at present there is only one).
- Exports all spectra in an -HX file to a set of ORTEC .CHN format spectrum files. The .CHN files can then be viewed and analyzed in more detail with ORTEC applications such as the GammaVision Gamma-Ray Spectrum Analysis and MCA Emulator.

The Micro Detective-HX Offline Analysis Program is a utility supplied with every instrument. It is run on a PC and provides extended functionality for use post-analysis.

The key features of the program are listed below.

1 Toolbar — Click to issue the main program commands.

2 File Information Section — Displays the name of the ICD1/ICD2 file pair currently open; its Location; and the instrument with which it was acquired, including the firmware version and the unit serial number (ID).

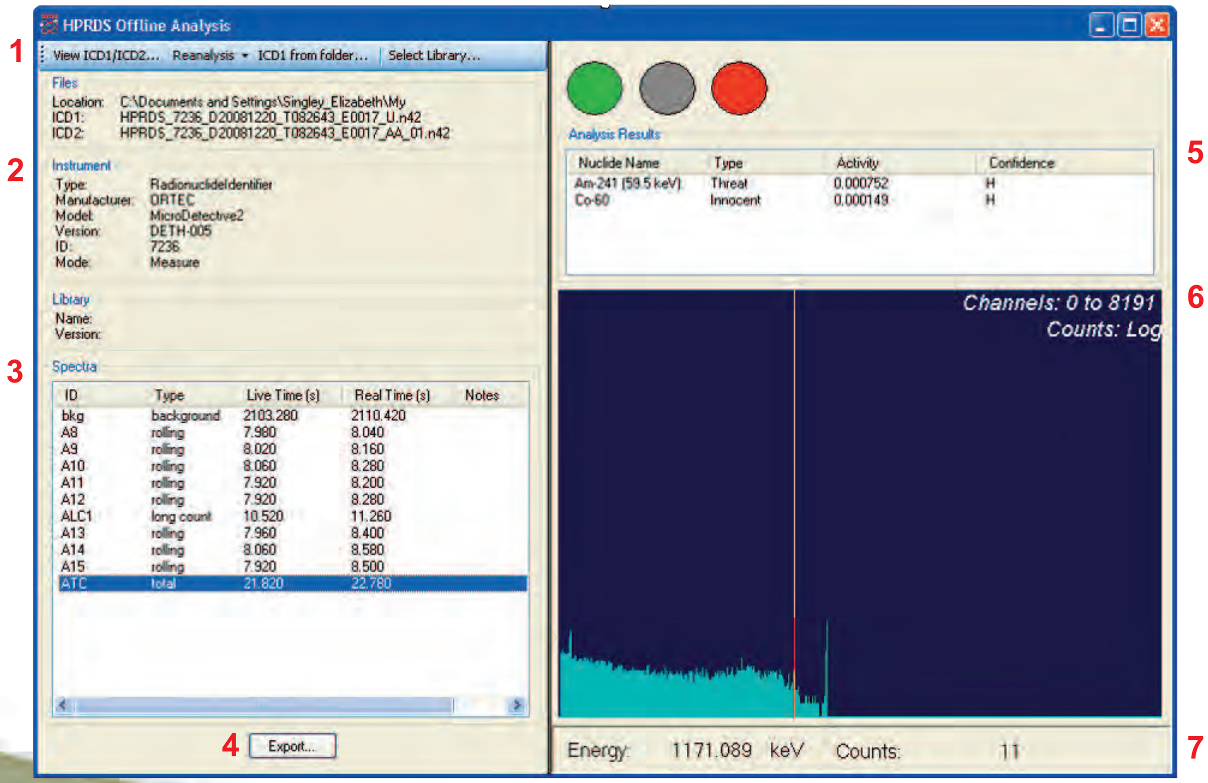
3 Spectra List — Lists all the component spectra in the current ICD1/ICD2 file pair, including the background spectrum, any 8-second "rolling window" Detect Mode spectra, any Long or Fixed Sample spectra, and the final cumulative spectrum.

4 Export Button — Exports all the component spectra in the current ICD1/ICD2 file pair to a set of ORTEC .CHN format spectrum files.

5 Analysis Results Section — Lists the nuclides found (if any), including the threat type (innocent, suspect, or threat), dose rate in mrem/hr, and confidence level (H — high or L — low). In conjunction with this list, the three simulated LED readouts "light" according to the innocent (green), suspect (yellow), and/or red (threat) nuclides identified.

6 Spectrum Window — A full-scale display (0 to 8191 channels) of the currently selected spectrum, in counts per channel, with logarithmic vertical scaling. This window includes a vertical marker line which can be moved with the mouse.

7 Marker Information Line — Shows the energy, in keV, and counts per channel for the current marker position.



Micro-Detective-HX

Micro-Detective-HX Technical Specifications

Dose Rate Visual over range indication and continuous audible alarm, user settable. Over-ride alarm at dose rates >10,000 µSv/hr.

Internal HPGe Detector P-type high-purity germanium. Coaxial construction. Crystal Nominal Dimensions 50 mm diameter x 40 mm length.

Cryostat and Cooler "Hardened" cryostat, with high-reliability, low-power Stirling cooler. The cryostat design is such that the Micro-Detective-HX may be switched off at any time and power subsequently re-applied, without having to wait for a full thermal cycle (full warm up before cool down), as is normal practice with a HPGe detector system. This feature greatly increases system availability during measurement campaigns.

Gamma Dose Rate Detector Two detectors determine the gamma dose rate over a wide range from <0.05 µSv/h to >10000 µSv/h, a dose-rate range of around six decades. For low dose rates, below ~20 µSv/h, the dose rate is determined from the Ge detector spectrum. For dose rates above this value, the internal compensated GM tube is used. Instrument switches between the two automatically.

Dose Rate Uncertainty <(–50% to +100%); continuous audible alarm at dose rates >10,000 µSv/h (fixed maximum threshold), user settable threshold below this.

Internal Neutron Detector Module Single ^{3}He tube: 4" active length, 0.5" diameter, 20 atm He^{3} fill pressure. High density Polyethylene moderator. 5.5 in x1.3 in x 1.3 in. approximately.

Digital MCA and Data Processor

Display VGA 640 x 480 TFT sunlight readable, touch sensitive, operate with finger or stylus.

Data Processor Marvel 806 MHz XScale.

Data Storage

Media To internal RAM and removable SD card.

Storage Scheme In passive monitor mode, no data files are saved. In Survey mode and Long and Fixed sample mode, ICD1 and ICD2 files are stored.

File Format DNDO ICD format (similar to ANSI N42.42) for data and results.

These files may be read, reanalyzed and exported to the Micro-Detective-HX Offline Analysis Program, which is included with the instrument. Exported files are in the well known ORTEC ".CHN" format and may be read by many programs used by Reachback teams such as CAMBIO and by ORTEC products such as MAESTRO and GammaVision.

Computer Interfacing USB connection to laptop. Data transfer by Microsoft® ActiveSync. Wi-Fi (802.11) communication software. Wireless Mobile MCB Server software.

GPS Internal NMEA compliant WAAS capable.

Digital MCA with Internal Storage of Multiple Spectral Data

Digital Noise Suppression "LFR Filter" ORTEC Patent Pending.

Conversion Gain 8k channel.

Maximum Number of Stored Spectra Unlimited on removable media.

Maximum Overall Dimensions (including handle, Ge detector endcap and shock absorbers) 14.7 in L x 5.75 in W x 11 in H (37.4 cm L x 14.6 cm W x 27.9 cm H).

Weight 15.2 lbs (6.9 kg).

Internal Battery Lithium Ion. 14.4 V, 6.2 Ah, 89 Wh, nominal. Up to 5 hours of battery life at 25°C when HPGe detector is cold. <4 hour time to charge. Internal battery is easily swapped through removal of snap shut battery door.

External Battery Battery lifetime may be extended indefinitely by the use of external battery packs. DETECTIVE-OPT-15 is recommended, weighs less than 3.25 lbs and extends lifetime to >10 hrs.

Input Power 10 to 17 V DC from battery or DC power supply (universal mains supply included). Battery charger circuit is inside instrument.

Power Usage Strongest during cool down: <100 Watt. While charging Battery: 5A nominal. Cold with fully charged battery <2A.

External Power DC Input and battery Charge Input. 2.5 mm coaxial connector with locking screw on collar.

Temperature

Operation Range: –10°C to 40°C.

Relative Humidity: <90% at 35°C, non-condensing.

Instrument Enclosure Sealed against ingress of dust and water. All perforations are sealed by rubber plugs (connectors, memory cards, etc.). Instrument is not designed to tolerate immersion.

External Connectivity to System

1 SD (Secure Digital) card slot (3.3 V).

1 USB connection for "ActiveSync" capability or MCA operation with external computer (ActiveSync and remote display software included).

Wi-Fi 802.11 communication software.

Wireless Mobile MCB Server software

1 Audio headphone jack.

Cool Down Time The high reliability cooler is designed for continuous operation. Between making measurements the unit is powered from a DC supply, car battery or other high capacity device. Initial cool down time depends on ambient temperature, but is typically <12 hours at 25°C.

Communication Software

The Micro-Detective-HX is a member of the ORTEC CONNECTIONS family. Remote MCA control and individual spectrum download, even over a network, is achieved simply, by the use of ORTEC CONNECTIONS products such as MAESTRO MCA Emulation software.

Multiple spectra may be block-transferred from the instrument controller to external PCs by the use of Microsoft ActiveSync. Third party products such as SOTI “Pocket Controller Enterprise” may be used to implement the 802.11 wireless feature to provide remote wireless control of the complete Micro-Detective-HX.

Mobile MCB Server

The Mobile MCB Server software application enables any ORTEC portable instrument installed with a PDA to communicate wirelessly with ORTEC software applications such as MAESTRO, GammaVision, and Detective-Remote. The Mobile MCB Server acts like a wireless version of the USB connection, allowing users to control and monitor any portable spectrometer through a wireless network.

Users can develop their own applications through the use of the optional A11 tool kit.

Micro-Detective-HX

Ordering Information

Model	Description
MICRO-DETECTIVE-HX	Light-Weight, Portable HPGe Identifier (Gamma and Neutron). Includes GPS, mains adapter, battery cable, shoulder strap, softside carry case and Microsoft ActiveSync software.
MICRO-DET-HX-PKG-1	Includes MICRO-DETECTIVE-HX Light-Weight, Portable HPGe Identifier (Gamma and Neutron), GPS, mains adapter, battery cable, shoulder strap, Microsoft ActiveSync software, MAESTRO software, and hardside wheeled transport case.
MICRO-DET-OPT-1	Rugged, waterproof, wheeled transport case.
DETECTIVE-OPT-15	Ultra battery extender.
MICRO-DET-ACC-BAT	Lithium-ion battery.
MICRO-DET-ACC-CHGR	Standalone battery charger and calibrator kit.
DETDX-EX-MCB-SW	Mobile MCB Server add-on software module for existing Detective family instruments installed with a PDA.
DET-SW-UPG	Upgrade to complete Detective-Pro PDA Software Application package.

Further battery charging and upgrade options are available.

Note: This brochure relates to instruments with the following revision levels:

Micro-Detective-HX Rev. N or later

ORTEC®
www.ortec-online.com
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801 South Illinois Ave., Oak Ridge, TN 37831-0895 U.S.A.
For International Office Locations, Visit Our Website

AMETEK®
ADVANCED MEASUREMENT TECHNOLOGY

AT2S Series - Two Stage (2.5W) TE Cooled SCD-13 Detectors

Ambient Temperature:	+25°C
Detector Operating Temperature	See model types below
Typical Cooler Power @/or near Max. Cooling:	1.8 volts @1.2 amps

Standard Specifications - Electrical
All detector specifications are at a bias voltage of 50 V/mm distance between electrodes applied across the detector and with a one megohm load resistor in series. All specifications apply at or near maximum cooling with the heat sink @ +25°C.

	Minimum	Typical	Maximum	Units
Wavelength of Max. Response	2.6	2.7		µm
D*(500K, 650 Hz, 1Hz)	2.2×10^9	3.3×10^9		cm $Hz^{1/2}$ w^{-1}
D*(I_{pk}, 650 Hz, 1 Hz)	2.0×10^{11}	3.0×10^{11}		cm $Hz^{1/2}$ w^{-1}
Element Resistance (Dark)	3.0	6.0	20.0	Megohms/□
Time Constant (not measured)		1750	3500	µsec
Rated Element Temperature			+65	°C
ΔT@/or near Max. Cooling	70	75		°C

For square or rectangular element sizes and/or packages not listed, please contact our application engineers, phone (707) 303-3837, or fax (707) 545-5113.

When using the table below, remove parenthesis and insert appropriate designation for package type in this space: Example: 6 for TO-66, 8 for TO-8.

Model Number	Element Size (mm)	Responsivity (λ_{pk}, 650) vw-1		Operating Temp	Standard Package Options
		Minimum	Typical		
AT2S-1( )	1 x 1	1.4×10^6	2.1×10^6	-50°C	TO-66, TO-8
AT2S-2( )	2 x 2	7.0×10^5	1.1×10^6	-50°C	TO-66, TO-8
AT2S-3( )	3 x 3	4.3×10^5	6.5×10^5	-45°C	TO-66, TO-8
AT2S-4( )	4 x 4	3.3×10^5	5.0×10^5	-40°C	TO-66, TO-8
AT2S-5( )*	5 x 5	2.7×10^5	4.0×10^5	-35°C	TO-66, TO-8
AT2S-6( )*	6 x 6	2.4×10^5	3.6×10^5	-25°C	TO-66, TO-8
* Minimum D*(λ_{pk}, 650, 1) $\geq 1.0 \times 10^{11}$ cm $Hz^{1/2}$ w^{-1}					

- To specify thermistor option for all TE cooled detectors, add the suffix -T or -TC (calibrated) to the model number.

Cryo-Cycle™ II Hybrid Cryostat

Features

- LN_2 redundancy
- Non-CFC/non-flammable refrigerant
- Low power demand
- Same footprint as standard LN_2 Dewar
- Long life Pulse-Tube cooler Lifetime (L5) >75 000 hours of continuous operation
- Remote read-out and control
- Low vibration/low electrical noise
- Available in dipstick and integral configurations
- 2-year full warranty + pro-rated warranty on the cooler

Benefits

- Low operating cost
- Higher up-time
- Field installable (dipstick version)
- Quiet
- No compromise on detector specifications

Description

The CANBERRA Cryo-Cycle™ II is a unique offering in the field of cryogenically cooled radiation detectors. The Cryo-Cycle II is described as a "hybrid" cryostat because it combines the advantages of electric cooling with the reliability of liquid nitrogen. The long-life Pulse-Tube cryocooler, condenses the boil-off N_2 gas back into the 25 liter Dewar. This unique capability provides the convenience of operating a detector for 12 to 18 months before LN_2 needs to be added, but at the same time keeps the detector cold in case of power failure. With the Cryo-Cycle II the LN_2 supply keeps the detector cold for up to one week without power. There is no interruption of cooling. There is no down-time due to partial warm-up as long as LN_2 level is maintained. There is no risk of detector failure because of temperature cycling. LN_2 lost during power outages may be replenished at any time.

The Cryo-Cycle II comes with a number of improvements allowing us to answer our customers' requirements even better.

Key Improvements

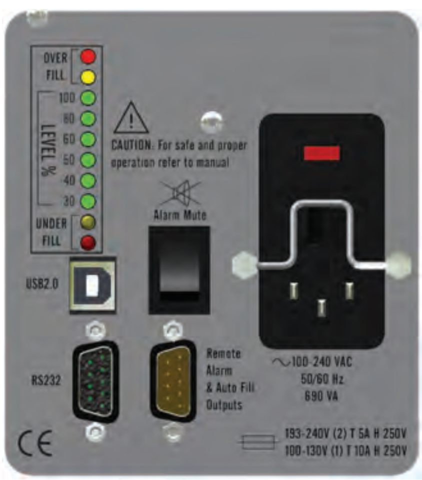
- Reduced cooler vibrations
- Improved LN_2 level sensor probe
- Single front panel
- RS-232 and USB interfaces
- Alarm and autofill relay outputs
- A Graphical User Interface (GUI)

The audible noise has been reduced to less than 60 dB(A), measured at 1 m distance, making the Cryo-Cycle II well suited for application in quiet laboratory environments.

The new LN_2 level sensor probe provides better accuracy. The measured LN_2 level is displayed through a continuous LED indicator scale on the front panel, allowing to better schedule periodic refills.

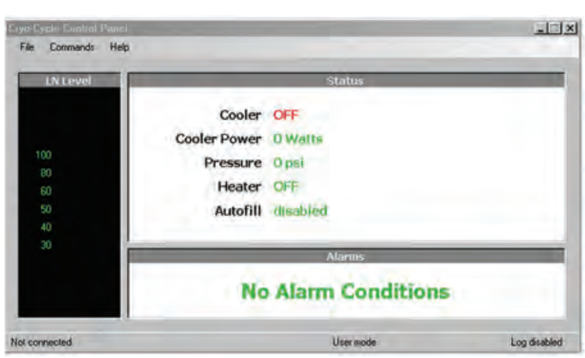
Cryo-Cycle II Hybrid Cryostat

All controls, connectors and indicators are integrated in a single front panel for easy access. The Cryo-Cycle II contains an auto-ranging power supply at 100-240 V and 50-60 Hz. The front panel is equipped with a DB9-M, a RS-232 and a USB connector. The DB9-M is a relay output for system status alarms and autofill functions. The serial connectors are used to connect to a PC. A dedicated GUI allows remote control and status monitoring.



Cryo-Cycle II front panel layout

The GUI is available through a Windows®-based software application, provided with the Cryo-Cycle II. This application needs to be installed on a PC connected to the Cryo-Cycle II through the USB or RS-232 serial ports. Minimum operating system requirements are Windows XP (SP3) or Windows 7.



Screenshot of the Cryo-Cycle II control panel application

The application can be operated in User mode or in Supervisor mode. The User mode only allows status and parameter monitoring, while the Supervisor mode, which can be password protected, allows access to the available commands. The displayed parameters and status indications can be continuously logged to a user-selectable .txt-file, saved on the PC's hard drive. Also each Cryo-Cycle II can be given a system name, allowing easy identification when multiple systems are monitored through the same PC. This name will be displayed in the application's title bar.

The Cryo-Cycle II is designed to accommodate both dipstick and integral configurations. Dipstick versions can be installed in the field, while integral versions must be assembled at the factory.

Due to the improved microphonics performance of the Cryo-Cycle II, when it is sold with a new CANBERRA detector, there will be NO degradation of the detector's resolution performance as stated on the detector's specification sheet. If the dipstick version is installed on older CANBERRA detectors some degradation of resolution performance may occur, depending on the age and configuration of the detector. CANBERRA guarantees no resolution degradation at energies above 500 keV and a maximum of 10% between 100 and 500 keV. Performance is not guaranteed below 100 keV. For detectors not manufactured by CANBERRA, resolution performance cannot be guaranteed.

The highly reliable and efficient Pulse-Tube cooler (lifetime of >75 000 hours) used in the Cryo-Cycle II contains a CFC free and non-flammable gas. The cooler is hermetically sealed, so no gas-refill is required. The compressor contains no oil or lubricant, so no contamination of the refrigerant occurs and no periodic filter/dryer exchange is required. This makes the Cryo-Cycle II virtually maintenance free. The nominal power consumption is very low (250 W), with a maximum of 450 W in transient operation. The Cryo-Cycle II is designed to operate between 10 °C and 35 °C.

CANBERRA's confidence in the Cryo-Cycle II is demonstrated by the two year full warranty on the complete system (detector included when purchased together) and an additional pro-rated warranty on the cooler. If the cooler fails after the second year, it will be repaired or replaced at 40, 60 or 80% of the list price in year three to five respectively. This pro-rated warranty applies to parts only.

Cryo-Cycle II Hybrid Cryostat

Specifications

PERFORMANCE

- CANBERRA guarantees detector performance as warranted by detector model with cooler in operation (on new detectors purchased with Cryo-Cycle II).
- LN_2 loss rate <3 liters/day typically (with cryocooler OFF).
- MAINTENANCE – Cleaning as required to keep air flow unrestricted.
- LEVEL INDICATORS – Linear LED scale on front panel.

CONNECTORS

- USB 2.0 – Remote control and status read-out.
- RS-232 – Remote control and status read-out.
- DB9-M – Relay output.

COOLING

- Forced air (internal fans).

POWER REQUIREMENTS

- 100–240 V ac, 50–60 Hz, 690 VA max. (auto ranging power supply).
- FUSE – (2) T 5 A 250 V (193-240 V ac Operation).
  FUSE – (1) T 10 A 250 V (100-130 V ac Operation).
- NOMINAL POWER CONSUMPTION – -250 W.

PHYSICAL

COLD HEAD (Excluding detector chamber)

- DIMENSIONS – 43.2 cm (17 in.) diameter x 61.0 cm (24 in.) high.
- WEIGHT – 28.2 kg (62 lb) empty, without detector.
- DEWAR-CAPACITY – 25 liters.

ENVIRONMENTAL

- OPERATING TEMPERATURE – +10 to +35 °C (50 to 95 °F) on standard models and configurations.
- OPERATING HUMIDITY – RANGE: 20% to 80% relative non-condensing.
- Meets the environmental conditions specified by EN 61010, Installation Category I, Pollution Degree 2.

SOFTWARE

- SYSTEM REQUIREMENTS – Windows XP (SP3) or Windows 7 (32-bit).
- .NET framework 3.5 (will be installed if not present, requires internet connection).

AVAILABLE DETECTOR MODELS

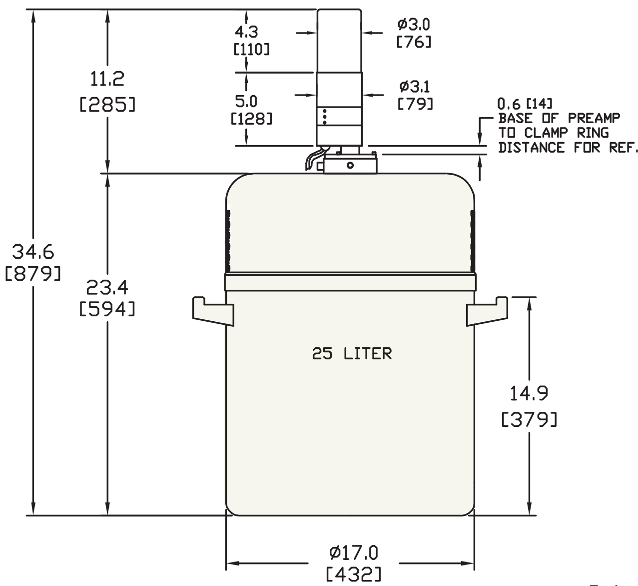
- Cryo-Cycle II can be ordered with all standard GC-, GX-, GR-, BE-, and GSW-detector models (see applicable detector specification sheets for details).

ORDERING INFORMATION

Model	Description
CCII-VD	Cryo-Cycle II for model 7500SL or 7500
CCII-HD	Cryo-Cycle II for model 7600SL or 7600
CCII-VI-SL	Cryo-Cycle II vertical integral Slimline
CCII-VI-F	Cryo-Cycle II vertical integral Flanged
CCII-HI-SL	Cryo-Cycle II horizontal integral Slimline
CCII-HI-F	Cryo-Cycle II horizontal integral Flanged
CCII-HI-U	Cryo-Cycle II horizontal U-Style

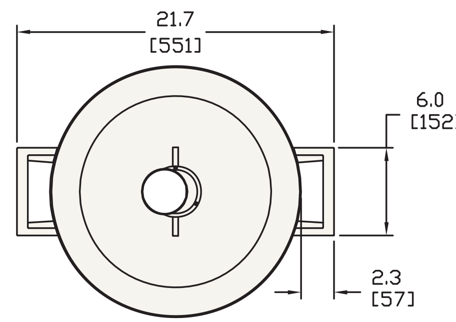
ISO 9001 SYSTEM CERTIFIED

Cryo-Cycle II with Vertical Dipstick cryostat (CCII-VD)



Side View

Cryo-Cycle II with 7500SL cryostat

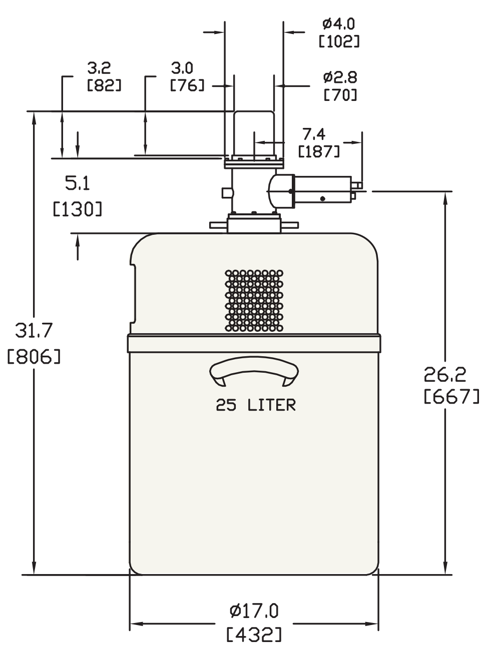


Top View

End cap dimensions depend on detector size. The tables below show the typical surface area or efficiency range vs. end cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end cap size is critical in your application.

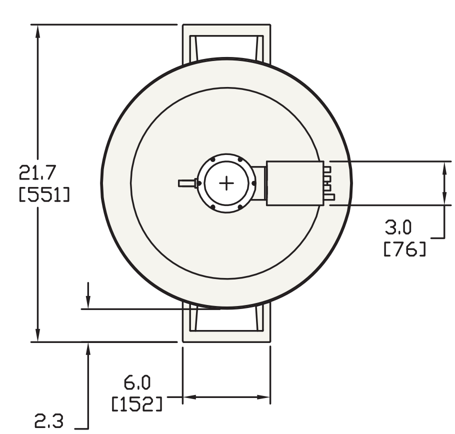
LEGe/BEGe, Nom. Area (mm^2)	End Cap Diameter, mm [in.]
=<2000	76 [3.0]
2800	83 [3.25]
3800	89 [3.50]
5000	102 [4.0]
6500	114 [4.50]

Coax Rel. Efficiency (%)	End Cap Diameter, mm [in.]
=<40	76 [3.0]
40-50	83 [3.25]
50-70	89 [3.50]
70-100	95 [3.75]
100-120	102 [4.0]
120-150	108 [4.25]
150	114 [4.50]



Side View

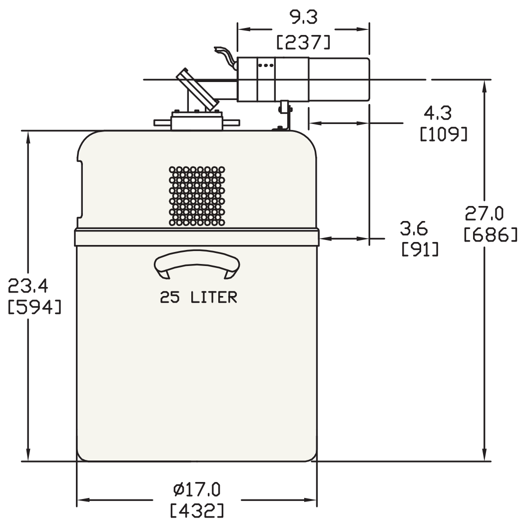
Cryo-Cycle II with 7500 cryostat



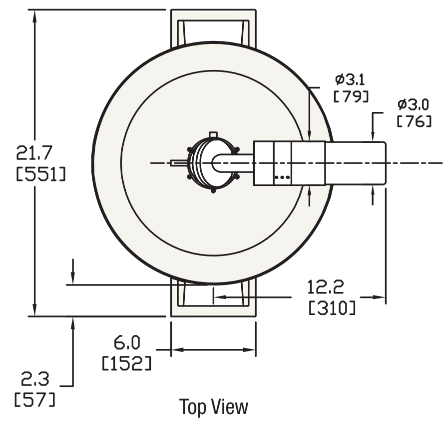
Top View

Cryo-Cycle II with Horizontal Dipstick cryostat (CCII-HD)

Cryo-Cycle II with 7600SL cryostat

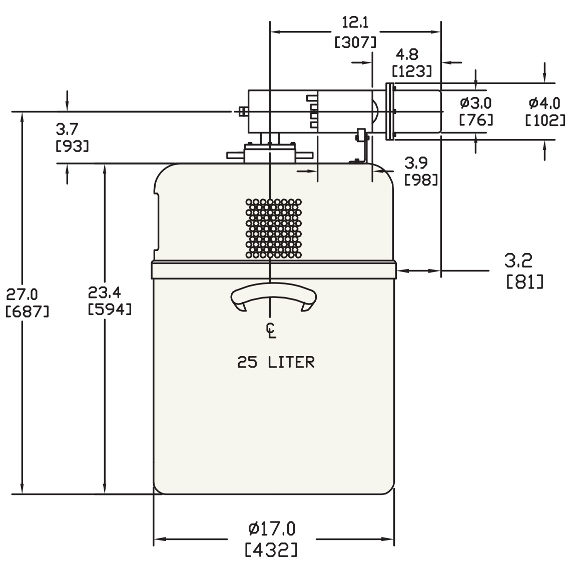


Side View

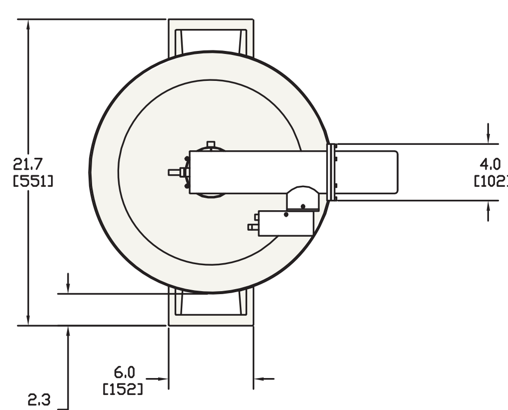


Top View

Cryo-Cycle II with 7600 cryostat



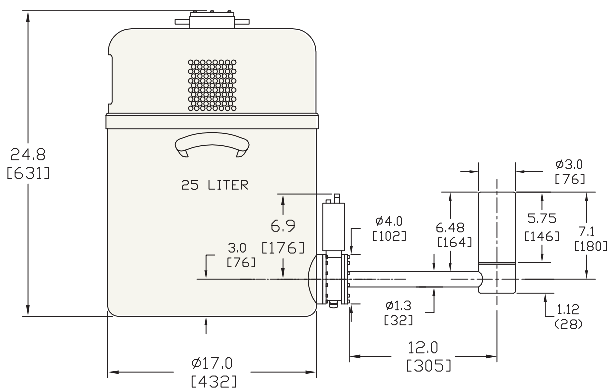
Side View



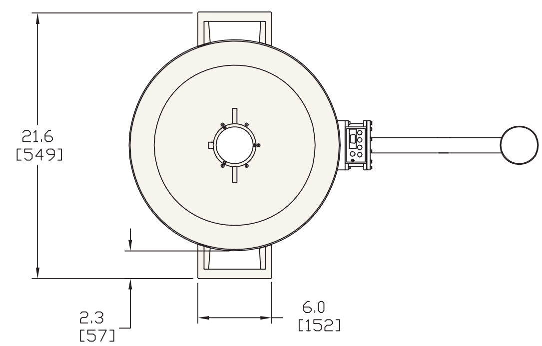
Top View

Cryo-Cycle II with Horizontal Integral cryostats

Cryo-Cycle II Horizontal Integral U-Style (CCII-HI-U)

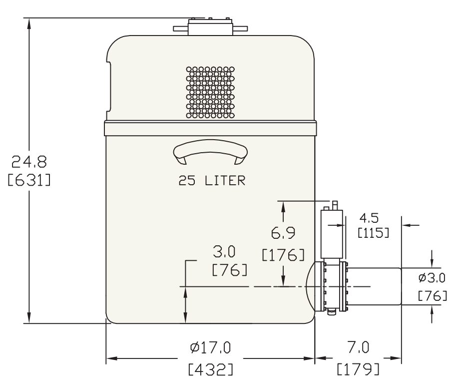


Side View

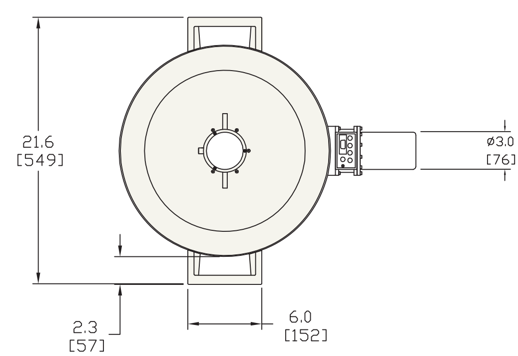


Top View

Cryo-Cycle II Horizontal Integral Flange Style (CCII-HI-F)

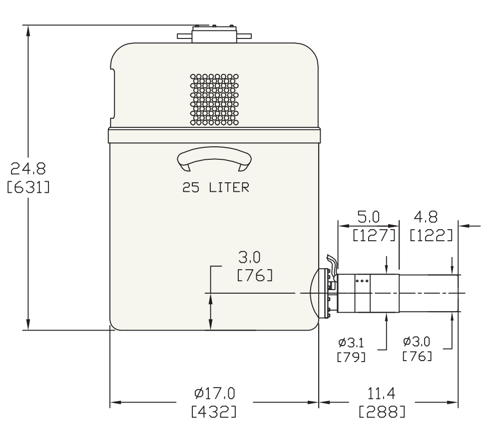


Side View

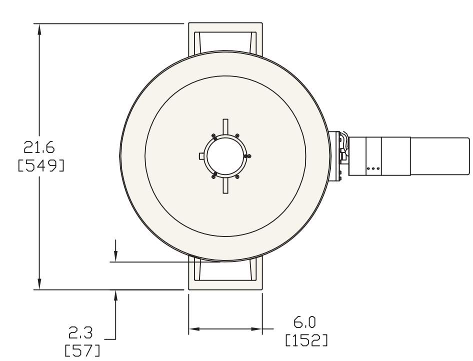


Top View

Cryo-Cycle II Horizontal Integral Slimline Style (CCII-HI-SL)



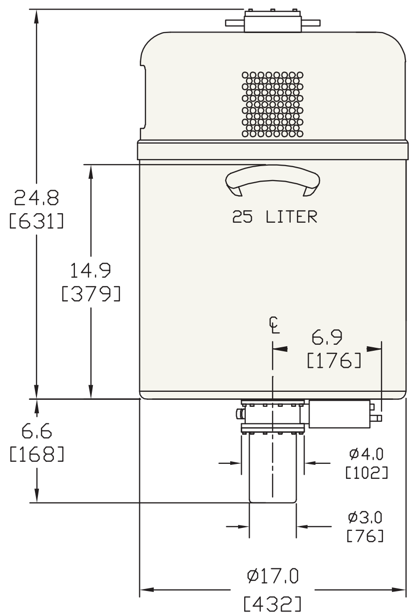
Side View



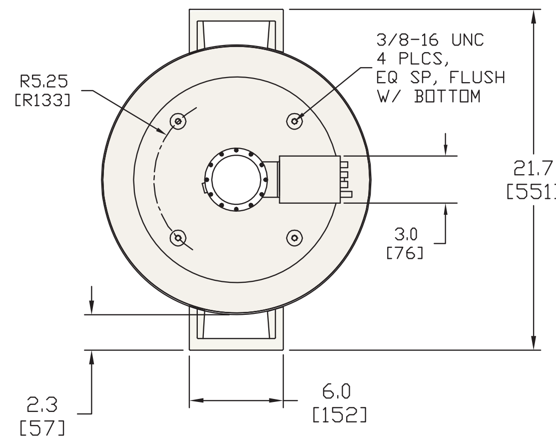
Top View

Cryo-Cycle II with Vertical Integral cryostats

Cryo-Cycle II Vertical Integral Flange Style (CCII-VI-F)

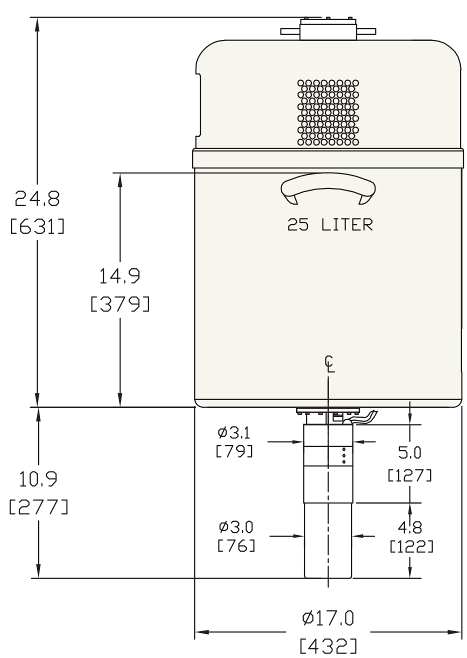


Side View

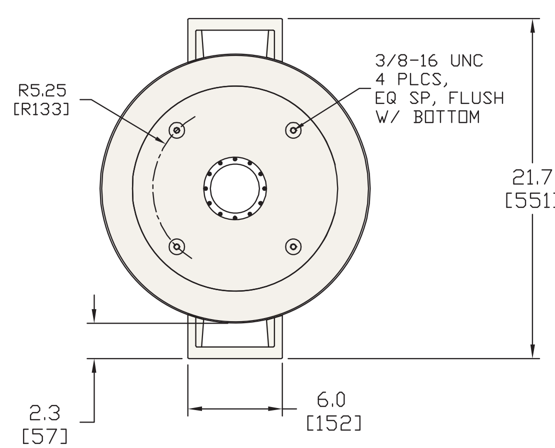


Bottom View

Cryo-Cycle II Vertical Integral Slimline Style (CCII-VI-SL)



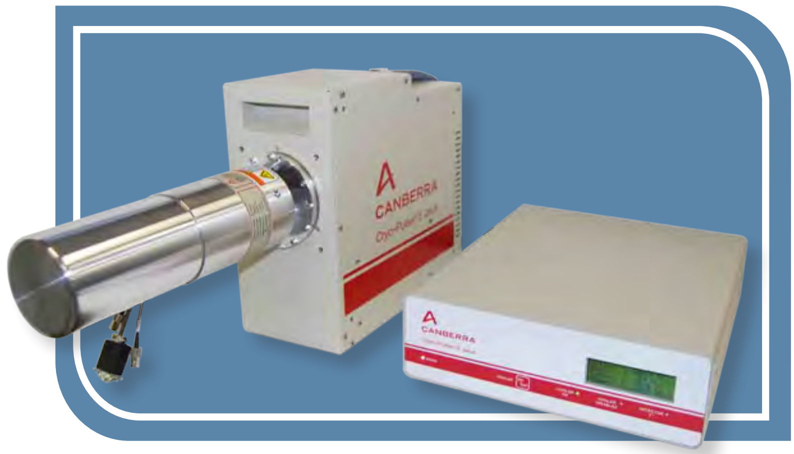
Side View



Bottom View

CANBERRA

Cryo-Pulse® 5 plus Electrically Refrigerated Cryostat



Features

- Completely LN_2 free
- Non-CFC/non-flammable refrigerant
- Long service life (>100 000 hours)
- No maintenance required
- Low power demand
- Low vibration/low noise
- Compact and lightweight
- No compromise on detector specifications
- Remote read-out
- Pulse-tube technology
- 2-year full warranty + pro-rated warranty on the coldhead

Benefits

- Safety
- Low operating cost
- High availability
- Expanded field of applications
- Quiet

Description

The Cryo-Pulse® 5 Plus is an electrically powered cryostat for use with HPGe radiation detectors. It utilizes a pulse tube cooler, a highly reliable technology originally used in military and space applications and which has proven its value for germanium detectors in the original Cryo-Pulse 5. Like its predecessor, the Cryo-Pulse 5 Plus still consists of a coldhead-assembly, to which the detector is attached, and an external power controller. The basic external design and interface of the coldhead have been preserved to maximize interchangeability between the previous and the new version. However the coldhead internals and the controller have been completely redesigned and new features have been added to further improve the performance and reliability and to answer our customers' requirements even better.

Key Improvements

Active and passive vibration reduction:

- Expanded range of HPGe detector models now available with electric cooling.
- Reduced audible noise.

Improved heat sinking, allowing operation up to 40 °C ambient temperature.

Graphical User Interface for remote control and status monitoring.

Integrated HV-inhibit circuit.

A pulse-tube cooler contains CFC free, non-flammable gas and is hermetically sealed, so no gas-refill is required. The compressor contains no oil or lubricant, so no contamination of the refrigerant occurs and no periodic filter exchange is required. This makes the Cryo Pulse 5 Plus completely **maintenance free**.

Cryo-Pulse 5 plus Electrically Refrigerated Cryostat

The cooler is integrated in a compact coldhead-assembly which is directly attached to the detector housing. The unit can operate in all orientations. The coldhead-assembly is connected to a bench-top power controller that produces the necessary output voltage to drive the compressor. The controller contains an auto ranging power supply at 100-240 V and 50 or 60 Hz. In addition to the relay output, the new controller is also equipped with a **RS-232 serial interface** to connect to a PC. A dedicated GUI allows remote control and status monitoring. Two BNC-connectors are foreseen on the rear panel to combine the inhibit signal of the preamplifier and the controller for enhanced detector protection. The Cryo-Pulse 5 Plus **controllers are backwards compatible** with the previous Cryo-Pulse 5 model coldheads.

A pulse tube cooler operates with a pressure wave instead of a piston, virtually eliminating wear and vibrations. This means pulse tube coolers are extremely reliable and have a very long **service life of over 100000 hours** or 11 years of operation. This life time estimation is documented in a paper that can be found under 'Detectors' in the Technical Literature section of the CANBERRA web site.

Although the compressor already produces very low vibration levels, all efforts are done to reduce these even more. Apart from shock mounts to isolate the compressor from the rest of the cooler and the detector housing, the Cryo-Pulse 5 Plus is equipped with an active vibration reduction system. An accelerometer inside the coldhead measures the vibrations generated by the compressor and feeds this signal back to the controller. The controller then adjusts the drive signal to the cooler so that vibrations are minimized. The system is even self-tuning such that it adapts to possible changes of the system's vibration characteristics over time. It is currently the best available technology in the field and allows CANBERRA to offer the broadest range of detector models available with **electric cooling** and continue to provide high-quality detector solutions with **no compromise on performance**.

Our confidence in the Cryo-Pulse 5 Plus is demonstrated by the **two year full warranty** on the complete system (detector included) and **additional pro-rated warranty on the coldhead**. If the coldhead fails after the second year, it will be repaired or replaced at 40, 60 or 80% of the list price in year three to five respectively.

Specifications

COLD HEAD (Excluding detector chamber)

- DIMENSIONS – 145 x 287 x 313 mm (5.7 x 11.3 x 12.3 in.) (W x H x D).
- WEIGHT – 17 kg (37.5 lb) approx.

POWER CONTROLLER

- DIMENSIONS – 280 x 88 x 315 mm (11 x 3.5 x 12.4 in.) (W x H x D).
- WEIGHT – 5.3 kg (11.6 lb).
- POWER CONTROLLER CABLE LENGTH – 3 m (10 ft).

OPTION

- Model CP5-C-25 – Controller Cable 7.5 m (24.5 ft).

POWER REQUIREMENTS

- 100–240 V ac, 50–60 Hz, 250 watts max. (auto ranging power supply).
- FUSE – 2x T3.15 A 250 V.

CONNECTORS

- 2X BNC-F – HV-inhibit.
- RS-232 – Remote control and status read-out (USB/RS-232 adapter provided).
- DB15-F – Relay output – cooler status and warm/cold indication.

COOLING

- Forced air (internal fans).

OPERATING TEMPERATURE

- +5 to +40 °C (41 to 104 °F) on standard models and configurations.

AVAILABLE DETECTOR MODELS AND OPTIONS

- Cryo-Pulse 5 Plus can be ordered with all standard GC-, GX-, GR-, BE-, GL-, GUL-detector models (see applicable detector specification sheets for details).
- The RDC-option is only available on the Flanged version.

PERFORMANCE

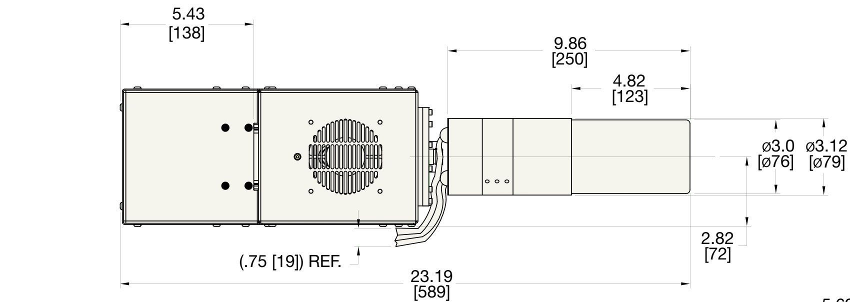
- CANBERRA guarantees detector performance as, warranted by detector model with cooler in operation.

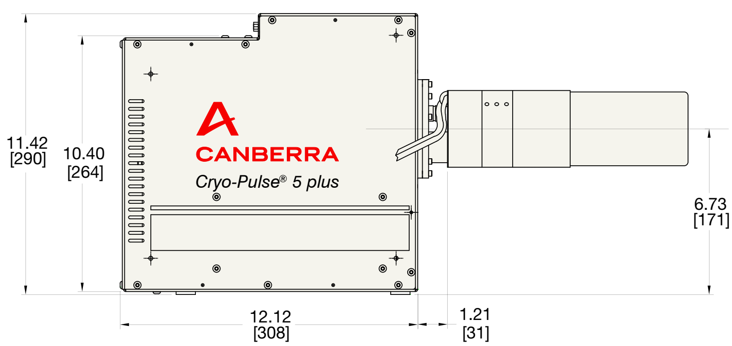
ORDERING INFORMATION

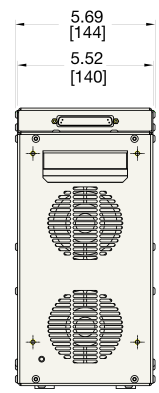
Model	Description
CP5-PLUS-SL	Slimline Cryo-Pulse 5 plus
CP5-PLUS-F	Flanged Cryo-Pulse 5 plus

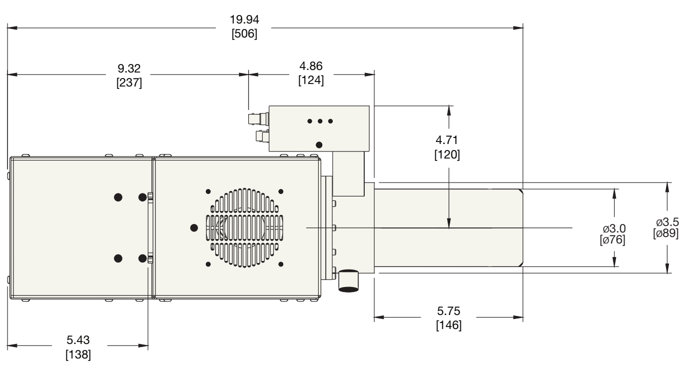
ISO 9001 SYSTEM CERTIFIED

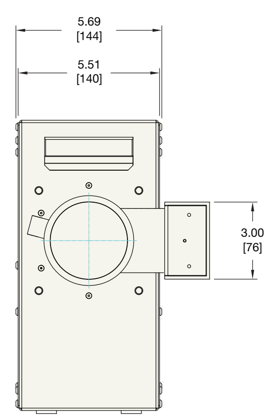
Cryo-Pulse 5 plus Electrically Refrigerated Cryostat











LEGe/BEGe, Nom. Area (mm^2)	End Cap Diameter, mm [in.]
=<2000	76 [3.0]
2800	83 [3.25]
3800	89 [3.50]
5000	102 [4.0]
6500	114 [4.50]

Coax Rel. Efficiency (%)	End Cap Diameter, mm [in.]
=<40	76 [3.0]
40-50	83 [3.25]
50-70	89 [3.50]
70-100	95 [3.75]
100-120	102 [4.0]
120-150	108 [4.25]
150	114 [4.50]

End cap dimensions depend on detector size. The tables above show the typical surface area or efficiency range vs. end cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end cap size is critical in your application.

CANBERRA

Slimline Cryostats

CANBERRA Slimline cryostats are designed so that the detector and electronics both fit in a cylindrical housing without any protruding flanges, valves, and preamplifier enclosures.

This compact configuration facilitates integration into shields and systems. Maintenance or exchange of the preamplifier is also very simple as it is located underneath the cylindrical cover, outside of the cryostat vacuum.

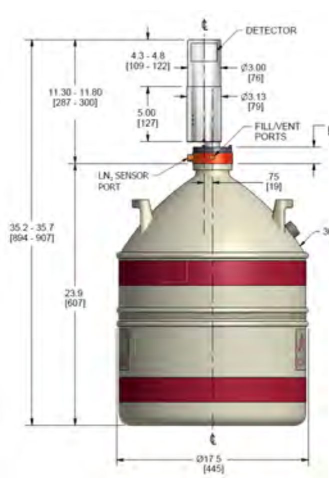
Vertical Slimline Dipstick cryostats can be fitted with a Remote-Detector Chamber (RDC). This RDC option separates the detector chamber from the Dewar and preamplifier and allows the use of a backshield so the lead shield completely surrounds the detector element.

Additionally the offset between the centerline of the RDC element and the cryostat coldfinger removes any direct “line-of-sight” between the detector chamber and the molecular sieves.

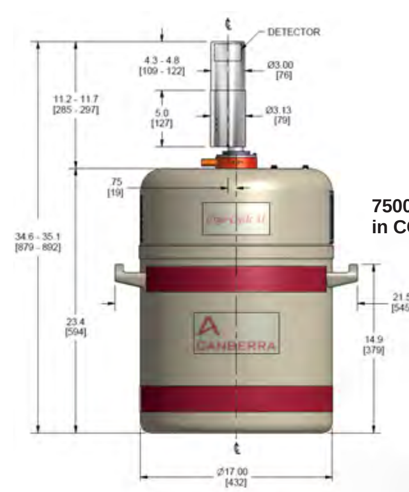
This design significantly reduces the radiation background on the detector. Standard lengths for the RDC option are 2, 4, 6, 8 and 10 inches. Custom lengths are available upon request.

End cap dimensions depend on detector size. The chart below shows the typical efficiency range vs. end-cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end-cap size is critical in your application.

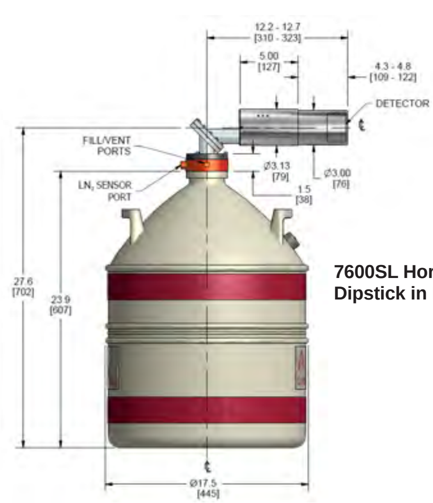
Rel. Efficiency (%)	Diameter in. (mm)
≤40	3.0 (76)
40-50	3.25 (83)
50-70	3.50 (89)
70-100	3.75 (95)
≥100	4.0 (102)



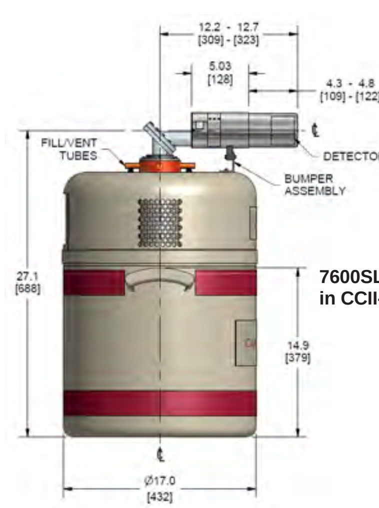
7500SL Vertical Dipstick in D-30 Dewar



7500SL Vertical Dipstick in CCII-VD Hybrid Cryostat

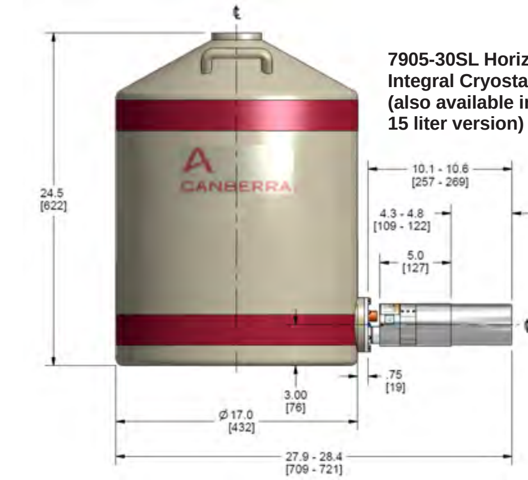


7600SL Horizontal Dipstick in D-30 Dewar

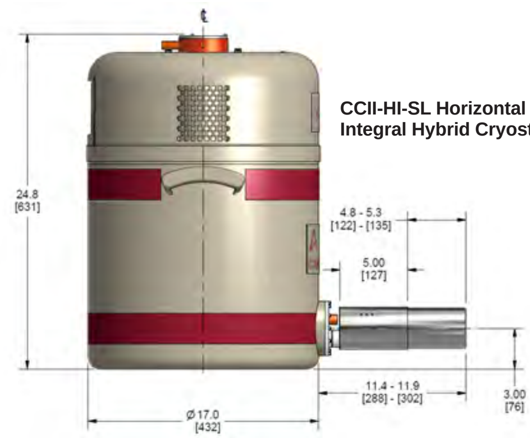


7600SL Horizontal Dipstick in CCII-HD Hybrid Cryostat

Slimline Cryostats

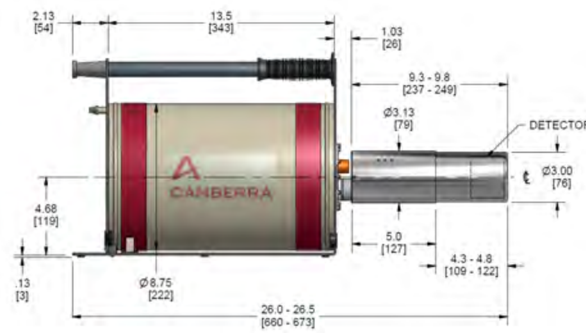


7905-30SL Horizontal Integral Cryostat (also available in 7.5 and 15 liter version)

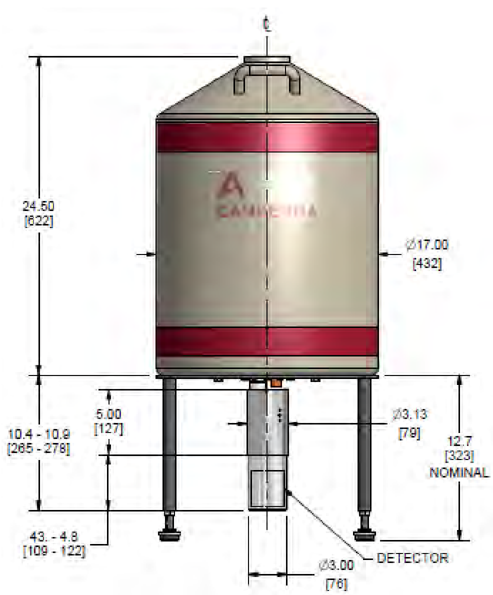


CCII-HI-SL Horizontal Integral Hybrid Cryostat

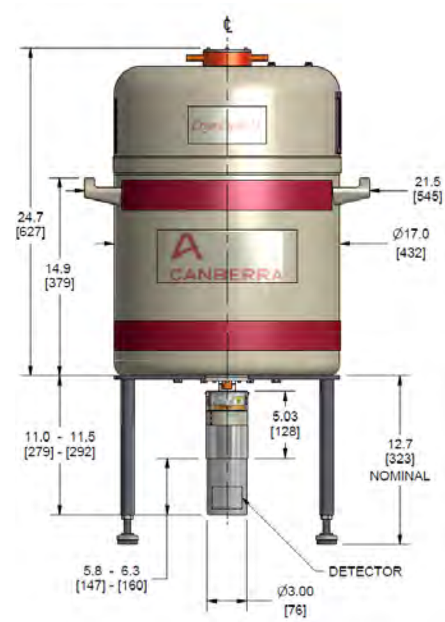
7935-2SL Portable Multi-Attitude Cryostat (2 liter MAC)



7935-7SL Portable Multi-Attitude Cryostat (7 liter Big MAC)

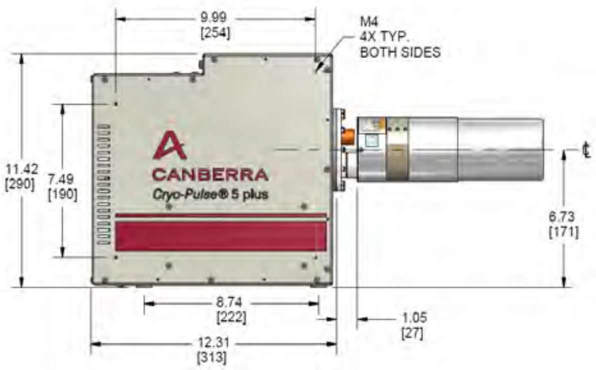


7906-30SL Vertical Integral Cryostat (also available in 7.5 and 15 liter version)



CCII-VI-SL Vertical Integral Hybrid Cryostat

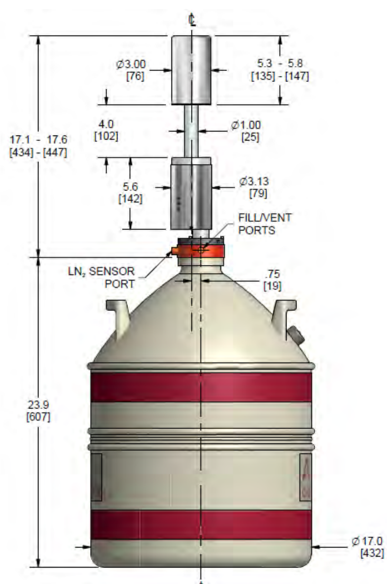
Slimline Cryostats



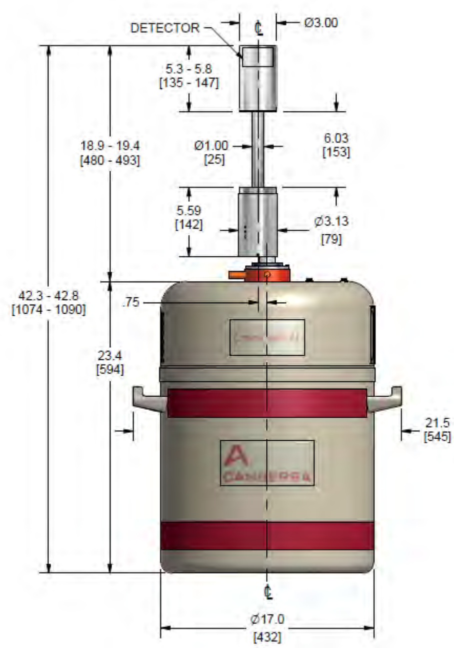
CP5-PLUS-SL Electrically-Cooled Cryostat

RDC option

Model 7500SL Dipstick cryostats can be fitted with an RDC option. Standard lengths for RDC elements are 2, 4, 6, 8 and 10 inches. The outline drawings below show examples of a 4 inch and 6 inch version as these are the most commonly used sizes. The RDC-4 is compatible with our model 747 and 767 lead shields. The RDC-6 goes with our model 777 lead shield.



7500SL-RDC-4 Vertical Dipstick in D-30 Dewar



7500SL-RDC-6 Vertical Dipstick Cryostat in CCII-VD Hybrid Cryostat

ISO 9001
SYSTEM
CERTIFIED

CANBERRA

Flanged Cryostats

The liquid nitrogen cryostat is the most important and least appreciated component in assuring reliable long term performance of a germanium detector system. CANBERRA manufactures its own cryostats to exacting quality standards to ensure long detector life.

There are two basic types of cryostats in use: the dipstick, in which the detector occupies a vacuum chamber having a dipstick-like tail which is inserted into the neck tube of a Dewar, and the integral, in which the detector chamber and Dewar share a common vacuum.

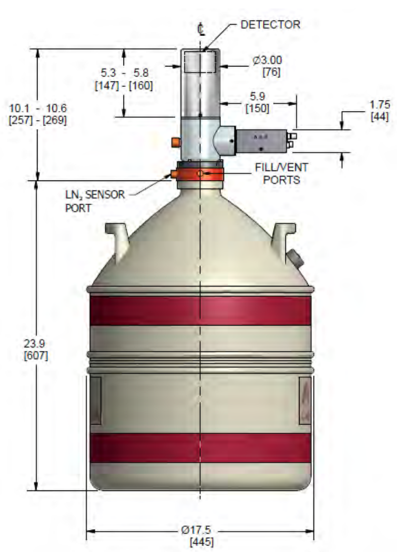
The standard configuration comes with a radial O-ring seal. A metal face seal is available as an option on detectors with a 3.0 in. (76 mm) diameter endcaps only. Metal seals are more rugged and, in general, provide a longer life time of the detector vacuum.

Flanged cryostats can be fitted with a Remote-Detector Chamber (RDC). This RDC option separates the detector chamber from the Dewar and preamplifier and allows the use of a backshield so lead shielding that completely surrounds the detector element can be installed.

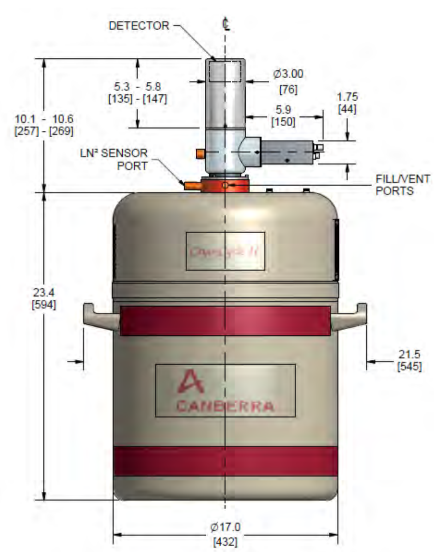
This significantly reduces the radiation background on the detector. Standard lengths for the RDC option are 2, 4, 6, 8 and 10 inches. Custom lengths are available on request.

End cap dimensions depend on detector size. The chart below shows the typical efficiency range vs. end-cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end-cap size is critical in your application.

Rel. Efficiency (%)	Diameter in. (mm)
≤40	3.0 (76)
40-50	3.25 (83)
50-70	3.50 (89)
70-100	3.75 (95)
≥100	4.0 (102)

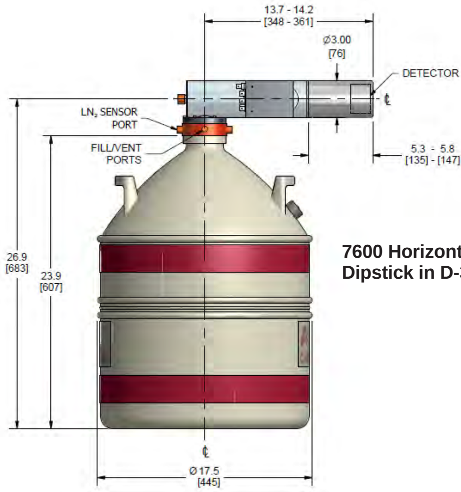


7500 Vertical Dipstick in D-30 Dewar

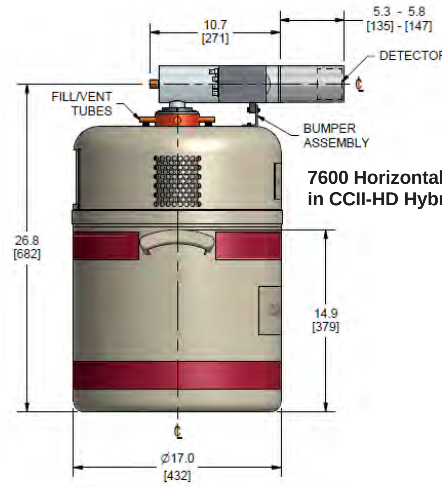


7500 Vertical Dipstick in CCII-VD Hybrid Cryostat

Flanged Cryostats

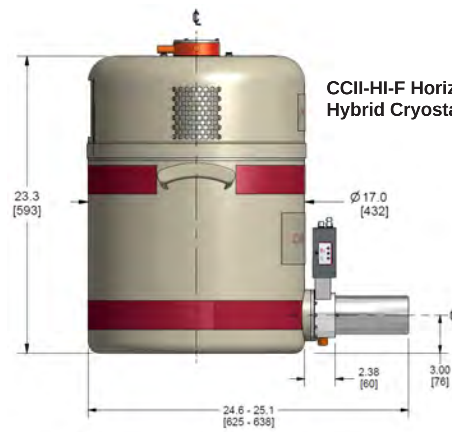


7600 Horizontal Dipstick in D-30 Dewar

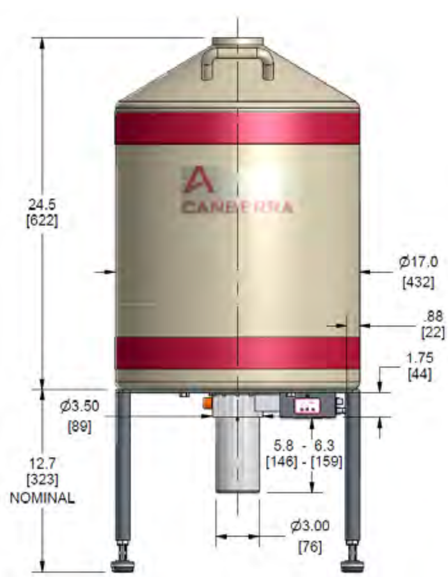


7600 Horizontal Dipstick in CCII-HD Hybrid Cryostat

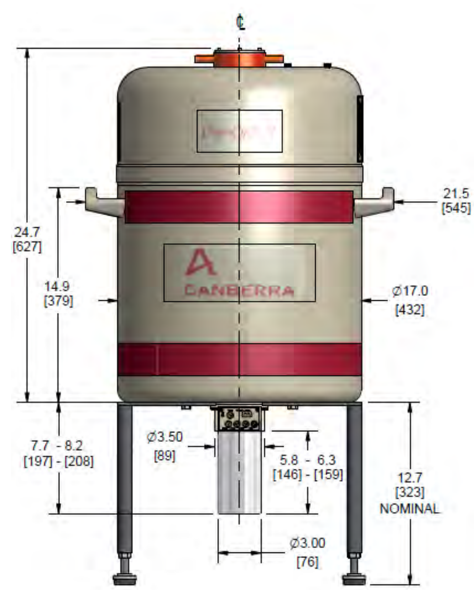
7905-30 Horizontal Integral Cryostat (also available in 7.5 and 15 liter version)



CCII-HI-F Horizontal Integral Hybrid Cryostat

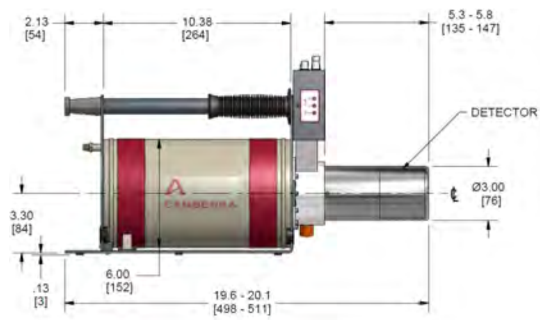


7906-30 Vertical Integral Cryostat (also available in 7.5 and 15 liter version)

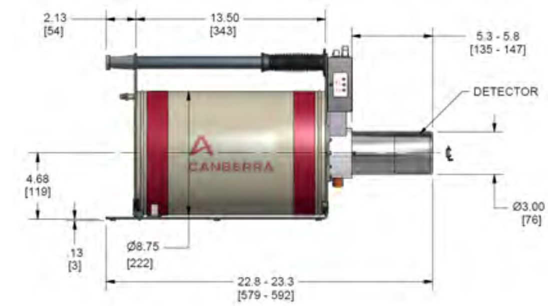


CCII-VI-F Vertical Integral Hybrid Cryostat

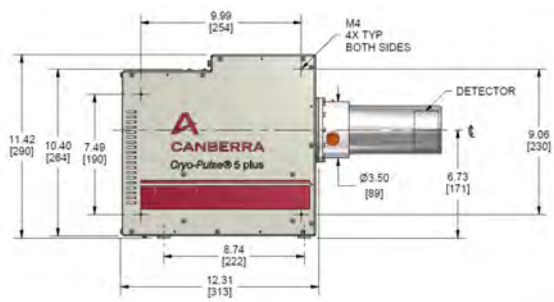
Flanged Cryostats



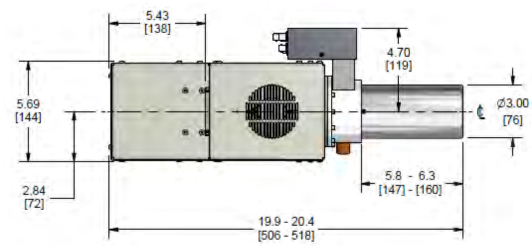
7935-2F Portable Multi-Attitude Cryostat (2 liter MAC)



7935-7F Portable Multi-Attitude Cryostat (7 liter Big MAC)



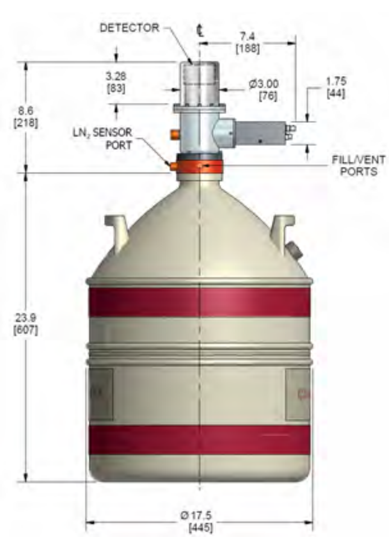
CP5-PLUS-F Electrically-Cooled Cryostat (side view)



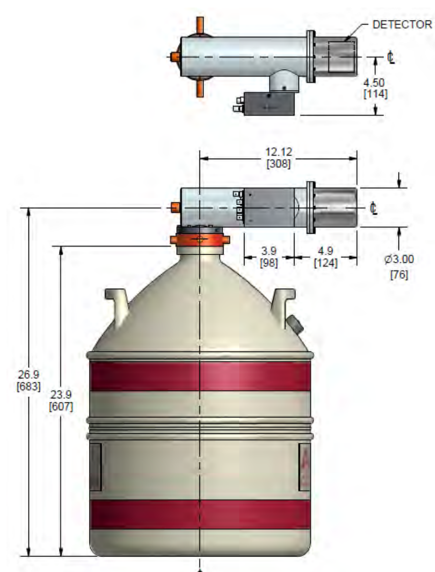
CP5-PLUS-F Electrically-Cooled Cryostat (top view – preamplifier can be oriented in other directions upon request)

Metal Seal Flanged Cryostats

(available on 3 in. (76 mm) diameter endcaps only)

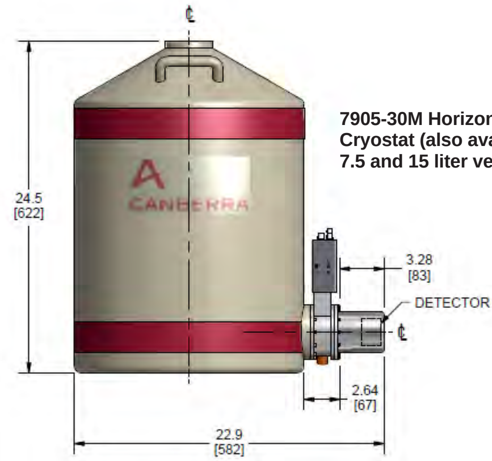


7500M Vertical Dipstick (Available in D-30 Dewar or CCII-VD Hybrid Cryostat)

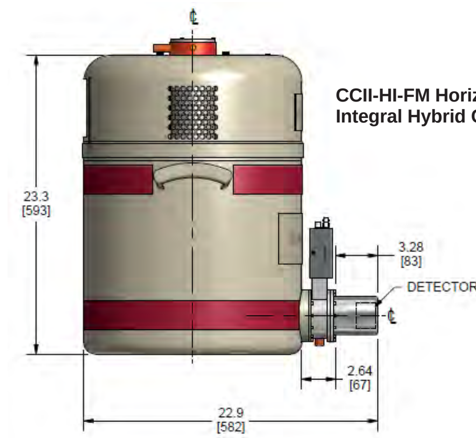


7600M Horizontal Dipstick (Available in D-30 Dewar or CCII-HD Hybrid Cryostat)

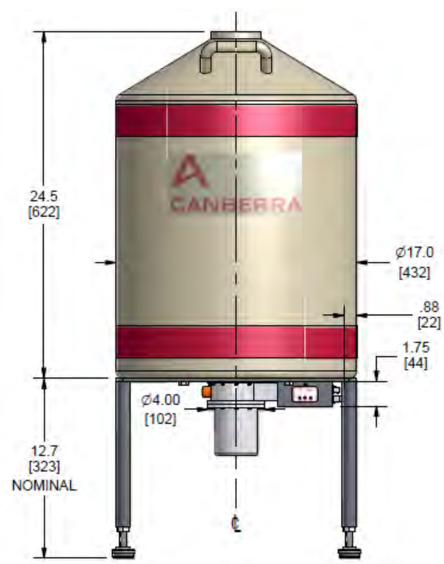
Flanged Cryostats



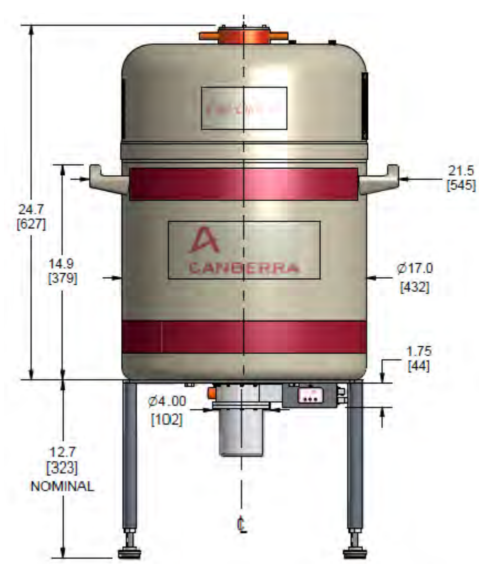
7905-30M Horizontal Integral Cryostat (also available in 7.5 and 15 liter version)



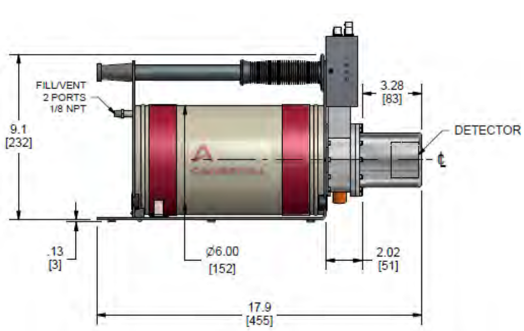
CCII-HI-FM Horizontal Integral Hybrid Cryostat



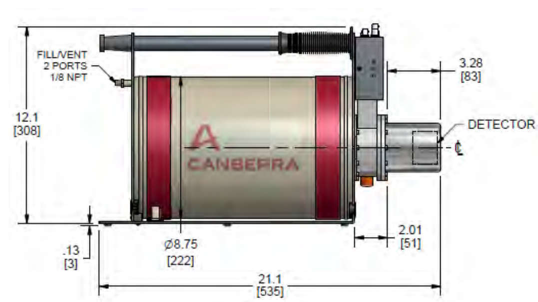
7906-30M Vertical Integral Cryostat (also available in 7.5 and 15 liter version)



CCII-VI-FM Vertical Integral Hybrid Cryostat

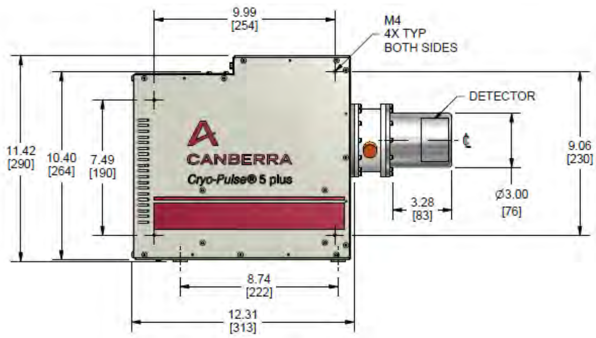


7935-2FM Portable Multi-Attitude Cryostat (2 liter MAC)



7935-7FM Portable Multi-Attitude Cryostat (7 liter Big MAC)

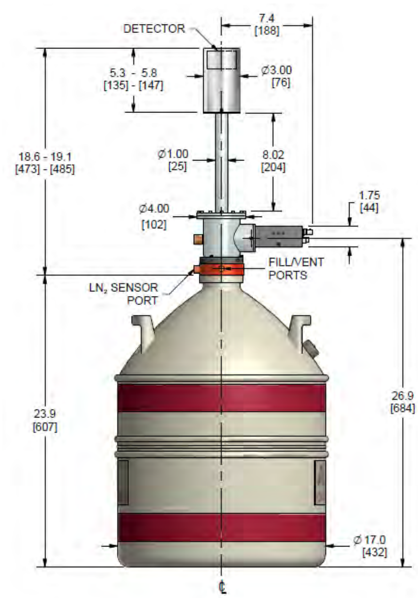
Flanged Cryostats



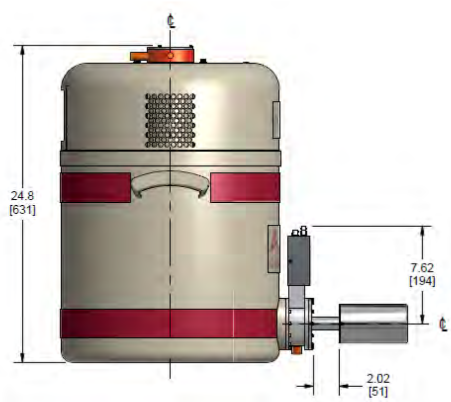
CP5-PLUS-FM Electrically-Cooled Cryostat

RDC option

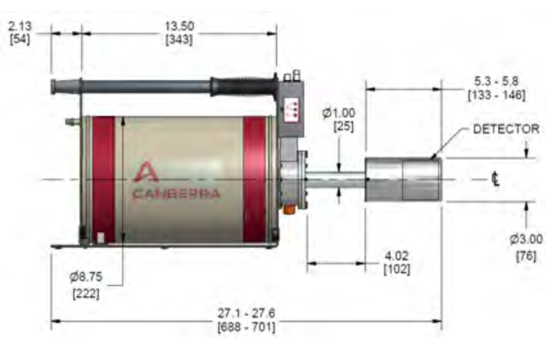
All flanged cryostat models (with exception of the vertical integral downlooking Cryo-Cycle™ II, model CCII-VI) can be fitted with an RDC option. Standard lengths for RDC elements are 2, 4, 6, 8 and 10 inches. Below are a few examples of LN_2 or electrically cooled cryostat models including the RDC option. The flanged Big MAC and Cryo-Pulse® 5 Plus with RDC-4 are commonly used in *in situ* counting (ISOCS™) systems.



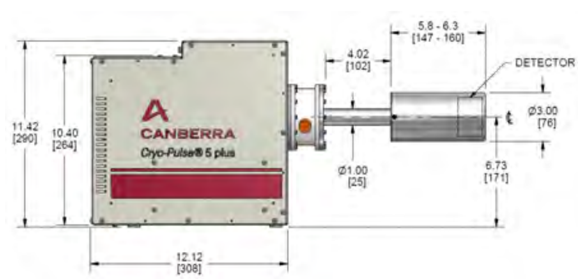
7500-RDC-8 Vertical Dipstick Cryostat in D-30 Dewar



CCII-HI-F-RDC-2 Horizontal Integral Hybrid Cryostat



7935-7F-RDC-4 Portable Multi-Attitude Cryostat (7 liter Big MAC)



CP5-PLUS-F-RDC-4 Electrically-Cooled Cryostat

Cryo-Cycle and ISOCS are trademarks of Canberra Industries, Inc.
Cryo-Pulse is a registered trademark of Canberra Industries, Inc.

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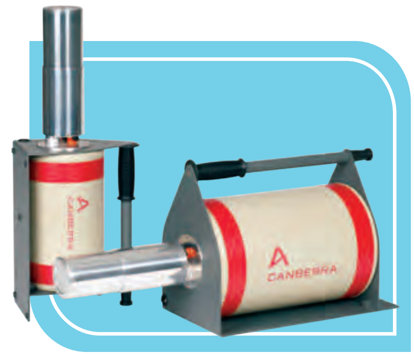
Features

- Operation in any orientation
- Light weight aluminum construction
- Slimline detector/preamplifier configuration
- Long holding time
- Warm-up sensor-bias disable

Portable Cryostats
MAC-Two Day
Big MAC-Five Day

Description



For applications requiring both portability and flexibility of use, the MAC (multi-attitude cryostat) is the answer. The unique fill and vent system employed by the MAC allows operation of the detector in any orientation without LN_2 spillage even when the Dewar is full. The small size, light weight, and ruggedness of the unit permit use of the unit in field conditions. The slimline detector chamber allows the unit to be shielded very effectively for use in low level counting applications.

The MAC detector consists of a Dewar having two fill and vent ports arranged so that one of the ports is the vent, regardless of the Dewar's orientation. This allows the Dewar to be operated in the horizontal position, vertically uplooking, or vertically downlooking, without loss of LN_2.

A single port version of the MAC and Big MAC is available on special order. This version has half the capacity and holding time of the standard product. A gravity-feed supply Dewar/stand is available for the single port cryostat. The single port cryostat is compatible with other brands, and it holds LN_2 in all orientations which may be important in some applications, e.g. for use in a submarine (see CANBERRA Model 7411).

The detector/preamp includes a sensor which provides a signal when the LN_2 is depleted. This output can be used to shut down the bias supply, to operate an alarm, or both.

The standard MAC features CANBERRA's slimline cryostat option in which a CANBERRA preamplifier is packaged behind the detector chamber within the confines of the 80 mm diameter snout. The slimline cryostat allows the detector to be installed in a shield with very little difficulty and with efficient use of shielding material. The snout is long enough to reach through 10-15 cm of shielding material and still accommodate Marinelli beaker samples.

A flanged version of the MAC is also available. This version makes use of a conventional box style preamplifier having bulkhead connectors (rather than pigtail connectors) and is somewhat more compact than the slimline version.

The MAC comes with detachable carrying handle assembly. With the carrying handle assembly removed, there are no obstructions beyond the outer diameter of the Dewar, and the unit can be readily installed in other scientific apparatus such as whole-body counters, scattering chambers or low-level counting systems.

Portable Cryostats MAC-Two Day Big MAC-Five Day

Both manual and automatic refill systems are available for use with the MAC. Since the MAC has separate fill and vent ports, the LN_2 supply and the vent lines can be made gas tight, thus avoiding the hazards of cold N_2 or LN_2 to either personnel or adjacent equipment.

The MAC is available as an option with most of the High Purity Germanium detectors offered by CANBERRA. Consult the CANBERRA Catalog for information on the wide variety of detectors that are available from CANBERRA.

Specifications

MAC

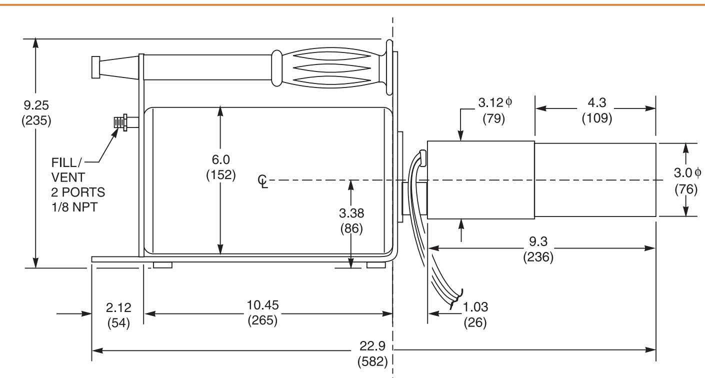
- WEIGHT – 5.1 kg (11.2 lb) empty; 7.1 kg (15.6 lb) full.
- LN_2 CAPACITY – 2.5 liters.
- HOLDING TIME – 2 days (typical detector size).
- COOL DOWN TIME – 2 hours, typically.
- FILL AND VENT PORTS – 3.2 mm (1/8 in.) NPT.

BIG MAC

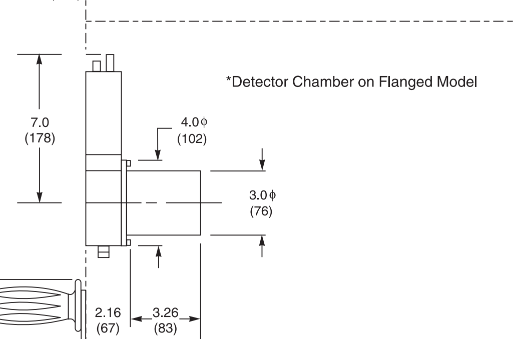
- WEIGHT – 7.9 kg (17.5 lb) empty; 13.6 kg (30 lb) full.
- LN_2 CAPACITY – 7.0 liters.
- HOLDING TIME – 5 days (typical detector size).
- COOL DOWN TIME – 2 hours, typically.
- FILL AND VENT PORTS – 3.2 mm (1/8 in.) NPT.

OPTIONS

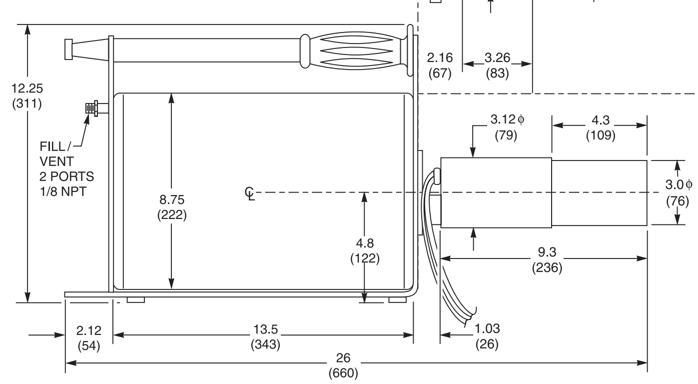
- Model 7415 Detector Lift Mechanism (for CANBERRA shields).



Model 7935SL-2 (Slimline Model)
Model 7935-2F (Flanged Model)*



End cap dimensions depend on detector size. The chart (below right) shows the typical efficiency range vs. end-cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end-cap size is critical in your application.



Rel. Efficiency (%)	Diameter in. (mm)
≤40	3.0 (76)
40-50	3.25 (83)
50-70	3.50 (89)
70-100	3.75 (95)
≥100	4.0 (102)

Model 7935SL-7 (Slimline Model)
Model 7935-7F (Flanged Model)*

CANBERRA

Retractable Cryostats

Features

- Variable geometry
- Windowless operation
- UHV compatible
- Rugged and reliable
- Use with Si(Li) or Ge detectors

Description

These retractable cryostats from Canberra are used with Si(Li), LEGe, and Ultra-LEGe detectors in x-ray applications. Retractable cryostats provide a means of moving the detector element in relation to the sample with both under vacuum. They also make it possible to operate the detector in windowless mode, i.e. without a window (absorber) between the detector element and the sample.

As with any detector that is not permanently sealed, care must be exercised in using windowless detectors to avoid contamination of the detector element. The vacuum chamber to which the detector is attached must be clean and dry and under good vacuum before the gate valve is opened. Under no circumstances is the detector to be exposed to atmosphere while it is cold. Damage to detectors caused by contamination is not covered under warranty.

The following standard models are available:

Model	Description
7905-R	Retractable unit with conventional window and sliding O-ring seal.
7905-WR	Windowless retractable unit with sliding O-ring seal.
7905-BWR	Windowless retractable unit with metal bellows seal.

The 7905-R provides variable geometry and vacuum chamber operation only. This cryostat comes with a conventional window. Refer to the relevant detector spec sheet for window options.

The 7905-WR provides variable geometry as well as windowless operation. An integral gate valve allows the detector to be retracted and sealed while the sample chamber is serviced. When the sample chamber is re-evacuated, the gate valve is reopened to admit the detector.

The 7905-BWR is similar to the 7905-WR. Instead of a sliding Oring seal, however, it has a flexible metal bellows which extends to provide detector movement. This version is preferred for UHV applications as outgassing properties are more favorable than that of a sliding O-ring seal. Of course, the Dewar and internal cryostat hardware are a source of outgassing in windowless systems but the cryogenic absorber used in the Dewar is fairly effective at pumping into the 10^{-4} – 10^{-5} Torr (133 – 13.3 kPa) pressure range and users report using such detectors successfully in vacuum systems operating at 10^{-8} Torr (13 x 10^{-5} Pa) or lower pressures.

Retractable Cryostats

Both the 7905-WR and 7905-BWR cryostats are factory equipped with a removable 1 mil Be window. This allows the user to check out the detector before exposing it to a foreign atmosphere. Once the detector is checked out and found to be operating properly, the window assembly can be removed. At this time the user becomes responsible for the welfare of the detector. The window assembly may be left in place indefinitely should the application not require windowless operation. These models are also equipped with a seal-off valve and detachable valve operator. This valve is located in a mini-conflat flange near the gate valve. It provides a means of pumping the space occupied by the gate valve and bellows or sliding seal when the beryllium window is in place and for evacuating the entire cryostat assembly when the beryllium window is removed.

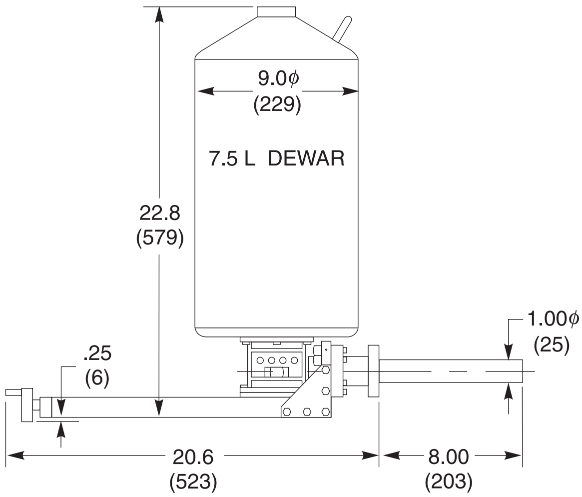
Detectors operating in windowless mode can pick up water vapor and other condensable contaminants from the user's vacuum system. Water vapor will freeze on the detector assembly, building up an ice layer which attenuates low energy photons. It isn't good for the detector element either. The 7905-WR and the 7905-BWR are equipped with an internal heater and temperature sensor which allow the user to warm up the detector assembly and evaporate the ice without emptying the cryostat. The heater has a resistance of 1325 ohms and accepts up to 10 watts of power at 115 V ac. The temperature sensor is a 100 ohm platinum resistance temperature detector (PRTD). Care must be exercised in using this feature to avoid overheating the detector assembly. Depending on conditions, deicing can be done in as little as four hours or so.

Some variations on the standard designs shown on the next page are practical while others are not. For example, it is practical to increase or decrease the stroke, to substitute a 15 liter Dewar, or to change the vacuum flange (conflat 2 3/4 in. is shown). It is not, however, practical to install a detector of greater than 80 mm^2 (Si(Li)) or 100 mm^2 (LEGe or Ultra LEGe) active area. Consult the factory for price and availability of any modifications you require.

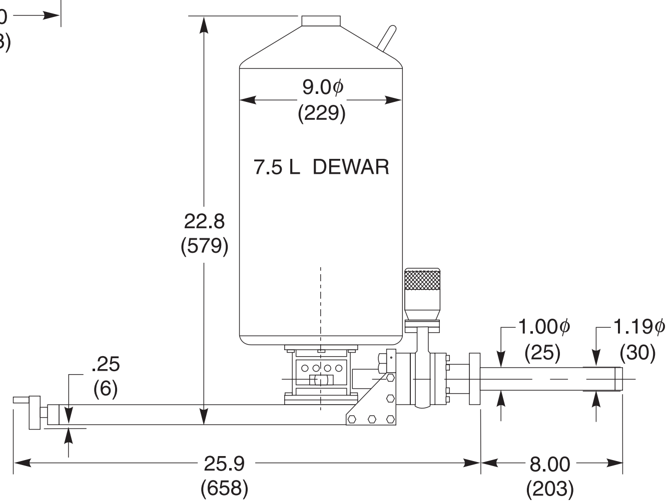
Other (than 1 mil) removable vacuum windows and removable contamination shields are available. The former make it possible to convert a windowless detector to windowed for applications not requiring extremely low energy response. The latter is a ultrathin window (not vacuum tight) which reduces the potential for contamination between the detector and the user's vacuum chamber.

Consult the factory for more information on these options.

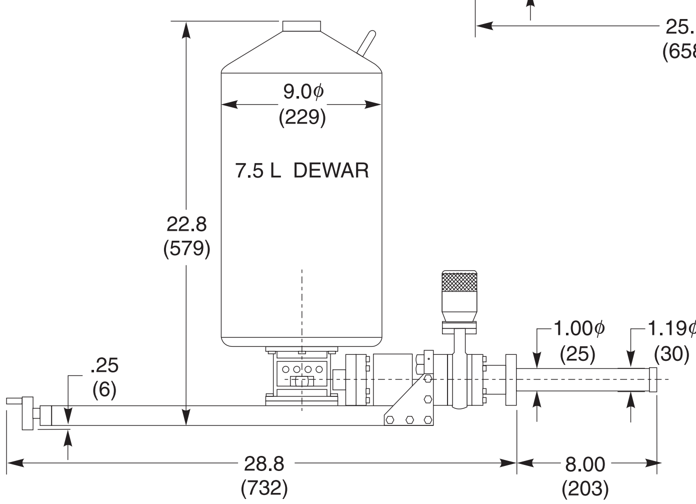
Retractable Cryostats



Model 7905-R



Model 7905-WR



Model 7905-BWR

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Model 7185/7186 LN$_2$ Gauge/Controller

Features

Models 7185 and 7186

- Digital level display
- High and low alarm setpoints
- Audible and visible alarm
- Alarm relay
- Sensor tailored to cryostat

Model 7186 Only

- High and low control setpoints
- Controlled ac output
- Solenoid valve with captive 3 m (10 ft) cord
- Hoses for fill and vent

Description

The Model 7185 LN$_2$ Level Gauge provides a digital display of LN$_2$ level in a Dewar or container along with adjustable low and high level setpoints which initiate audible and visible alarm signals as well as a relay output for remote monitoring. The display shows liquid level from 0-100% of the active sensor length. It can be programmed to read out in inches or centimeters. Sensors are designed, sized, and configured for CANBERRA dipstick and integral cryostats. For portable cryostats refer to the Model 2541 Controller. Consult the factory for applications involving non-CANBERRA cryostats.

The Model 7186 provides the same functions as the 7185. In addition it has adjustable low and high level control setpoints and a relay which provides line voltage to a controlled ac output for operation of a solenoid valve. The control and alarm setpoints are readily adjustable by means of front panel controls. Setpoints are stored in non-volatile memory. This ac outlet is powered from the time the low setpoint is reached until either 1.) the high setpoint is reached or 2.) the user-programmed time-out is reached. The 7186 includes a cryogenic solenoid valve as well as fill and vent hoses. LN$_2$ supply containers are available from CANBERRA for a complete automatic LN$_2$ Fill System.

Both models operate on line voltage of 100, 115, 200, or 240 V ac, 50 or 60 Hz, internally selected. This line voltage is provided on the controlled ac outlet.

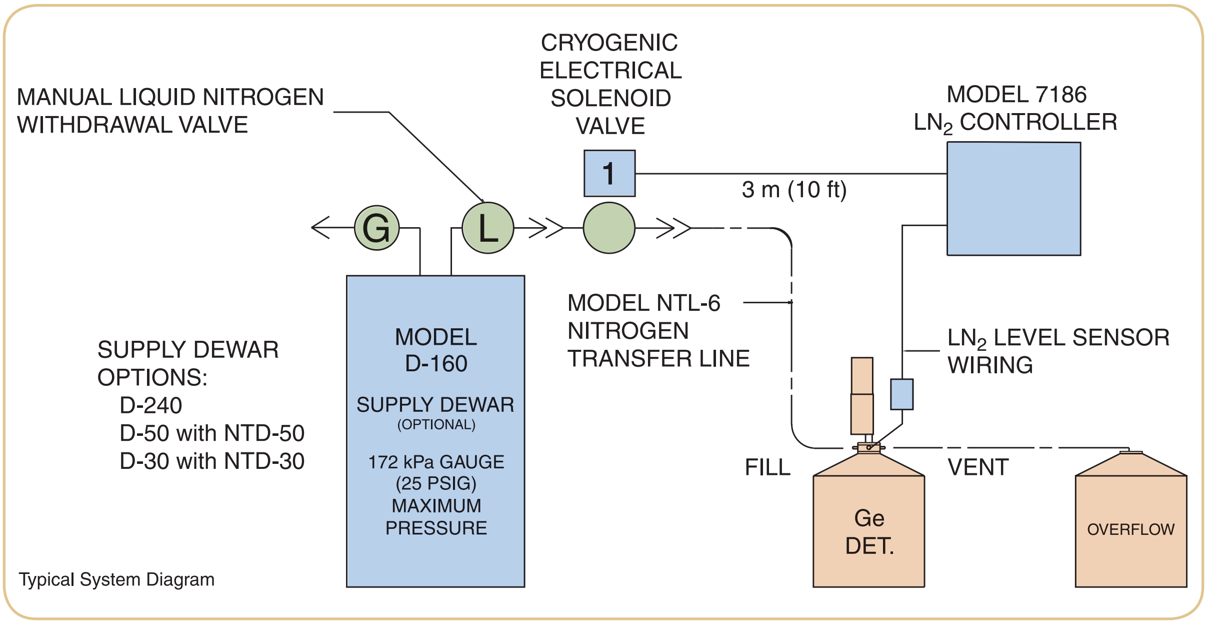
The 7186 Controller requires a source of LN$_2$ at a pressure of 34 to 172 kPa gauge (5 to 25 psig). CANBERRA D-160 and D-240 containers or their equivalents are highly recommended. A self-pressurizing withdrawal device (NTD-30/50) with a 30 or 50 liter Dewar can be used but it is not highly recommended because of marginal capacity and pressure for most applications. The liquid quality must be good at the point of consumption. This means there must be no ice in the liquid and that the supply line must not be lossy (causing excess vaporization).

An overflow container may be required if there is no safe place for the discharge of overflow gas and liquid. **WARNING:** Malfunctions can result in the entire contents of supply containers being dumped through the system. CANBERRA takes no responsibility for such accidents. The user is responsible for the installation and for the safety measures that are needed in this application.

Model 7185/7186 LN2 Gauge/Controller

ORDERING INFORMATION

- Specify model number.
- Specify cryostat type and capacity (model number).
- Specify line voltage.
- See LN_2 accessories for options.



Typical System Diagram

CANBERRA

Features

- Automatic protection against accidental detector warmup
- Delayed shutdown saves experiments
- Audible, visual and contact closure outputs

Model 1786A Detector LN_2 Monitor

Description

The Model 1786A Detector LN_2 Monitor protects LN_2-cooled detector systems against accidental warmup by monitoring liquid level in the Dewar and providing audible and visual warning of low liquid levels. It provides a signal for remote shutdown of Detector Bias Supply which has an Inhibit input. This single-width NIM module is suitable for most dipstick and integral type cryostats, but is not suitable for portable cryostats.

When your LN_2 sensor detects a problem, the LN_2 Monitor has provisions for turning off high voltage when an alarm condition occurs to protect detectors and electronics from damage. Shut-down does not occur until at least 20 minutes after the condition is sensed, and well before total depletion of the liquid nitrogen, so ongoing experiments can continue without interruption.

The Model 1786A must be manually reset following a power interruption. This will prevent HV Bias from coming on automatically (and abruptly) when the power is restored.

Specifications

INPUTS

- LN_2 DET. – Rear panel BNC connector accepts input signal from the LN_2 sensor.

OUTPUTS

- H.V. CONTROL – Rear panel contact closure output is grounded during alarm conditions; open circuit during normal conditions.

INDICATORS

- H.V. OFF – Front panel indicator lamp lights when the controlled circuit and H.V. CONTROL outputs are disabled.
- BUZZER – Internal buzzer gives audible warning of an alarm condition.
- LIGHT – Front panel LN_2 indicator light gives visual warning of alarm condition.

CONTROLS

- ACTIVATE-SETUP – Front panel toggle switch disables high voltage to allow alarm circuits to be set and checked without damage to associated electronics.
- LN_2 – Front panel lighted pushbutton switch; pressing it clears the alarm once alarm situation is corrected.

ACCESSORIES

- LN_2 SENSOR KIT – Includes a flexible sensor assembly, a BNC connector, and instructions for installing the sensor in standard CANBERRA cryostats. The kit will be installed by CANBERRA if the 1786A is ordered with a detector, a cryostat collar (CC-30), or a Dewar neck plug assembly.

CONNECTORS

- LN_2 DET. and H.V. CONTROL – Rear panel BNC, UG-1094/U.

POWER REQUIREMENTS

+24 V dc – 40 mA	+12 V dc – 185 mA
–24 V dc – 0 mA	–12 V dc – 5 mA

PHYSICAL

- SIZE – Standard single-width NIM module 3.43 x 22.12 cm (1.35 x 8.71 in.) per DOE/ER-0457T.
- NET WEIGHT – 1.2 kg (2.7 lb).
- SHIPPING WEIGHT – 1.9 kg (4.2 lb).

CANBERRA

LN_2 Accessories

Model D-2 LN_2 Fill Device

- Self-pressurizing device for filling portable cryostats
- Uses non-pressurized LN_2
- Capacity − 2 liters
- Two charges fill MAC, 5-6 charges fill Big MAC

Model D-30; D-50 LN_2 Storage Dewar

- LN_2 capacity (liters) – 30/50
- Diameter – 43 cm (17 in.)
- Height – 61.5/89.4 cm (24.2/35.2 in.)
- Loss rate (liters per day) – 0.5/0.6
- Shipping weight 11.8 kg (26 lb)

Model D-160 LN_2 Storage Tank

- 160 liter capacity
- 152 kPa (gage) (22 psig) relief pressure
- 1.5% per day loss rate
- Diameter – 51 cm (20 in.), height – 1.47 m (58 in.) (no casters)
- Shipping weight 100 kg (220 lb) empty

Model NTL-6 Nitrogen Transfer Line

- Insulated latex transfer line
- 3/8 in. ID x 1/8 in. wall x 6 ft long

Model D-30/OS Offset Neck Dewar

- Provides horizontal offset to detector chambers
- Neck to be offset by 12.7 cm (5 in.)
- Replaces D-30 Dewar in dipstick cryostats

Model NTD-30; NTD-50 LN_2 Withdrawal Device

- NTD-30 for use with D-30
- NTD-50 for use with D-50
- Pressure gauge
- 34.5 kPa (gage) (5 psig) relief valve
- Manual LN_2 valve
- Shipping weight 2.7 kg (6 lb)

Model D-240 LN_2 Storage Tank

- 240 liter capacity
- 152 kPa (gage) (22 psig) relief pressure
- 1.0% per day loss rate
- Diameter – 66 cm (26 in.), height – 1.63 m (64 in.) (with casters)
- Shipping weight 122 kg (270 lb), empty

Model RB-1 Roller Base for D-30 or D-50

- Adjustable
- Stable four-wheel design

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Low Background Detector Systems

INTRODUCTION

The term "low background" is used fairly indiscriminately in describing gamma analysis systems. The one common denominator for such systems is some form of shielding, but beyond this, anything goes. To bring some order to our own product line and to help customers distinguish the classes of systems, CANBERRA has chosen to categorize low-background gamma analysis systems as follows:

LOW-BACKGROUND

Ge detectors in a variety of cryostat types with lead shielding of 2-4 inch (5-10 cm) thickness. The only cryostats specifically excluded from this class are modular (convertible) types in which the molecular sieve adsorber is necessarily located near the detector element.

ULTRA LOW-BACKGROUND

Ge detectors in cryostats that are A: designed for shielding effectiveness and B: constructed from materials that are notably low in background. The complementary lead shields are also made from select, low-background materials and are at least 4-6 inches (10-15 cm) thick. CANBERRA uses the term Ultra Low-Background to describe standardized detectors and shields which are described in the following pages. These standard products offer performance normally associated with much more expensive custom systems.

SPECIALTY ULTRA LOW-BACKGROUND

Systems in this class are designed for the specific application at hand. This type of system usually involves user specified design and/or performance criteria and close collaboration between the user and CANBERRA throughout the project – from inception to installation.

It is this class of system where active shielding (cosmic guards or Compton suppression) is often used. CANBERRA has a wealth of experience in building such systems and we welcome your inquiries should standard Low Background or Ultra Low-Background systems not satisfy your needs.

Ask for our Application Note entitled Ultra Low-Background Detector Systems for more information.

TYPICAL RESULTS

The following 50 000 second background spectra were taken with detectors having 100% relative efficiency. Spectrum A was taken without shielding. Spectrum B was taken with the detector in a standard cryostat (7500SL) operating in a standard 4 in. thick Lead Shield (747). Spectrum C was taken with the detector in an Ultra Low-Background Cryostat (7915-30 ULB) operating in a 15 cm (6 in.) thick ULB (Model 777) Lead Shield.

Comparative Background Counts are given below:

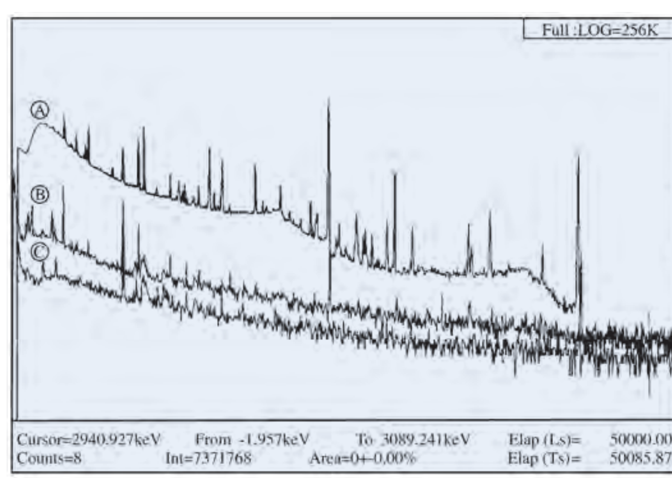
	Without Shield	Standard Cryostat and Shield	ULB Cryostat and Shield
Total Counts/Sec (50-3000 keV)	142.3	3.35	1.84
Peaks Found	78	31	13

Of the thirteen peaks found in the spectrum from the ULB system only one, the 2.614 MeV peak from ^{208}Tl is a normal background line. All the rest are attributed to cosmic ray interaction in the shield and detector.

A listing of these peaks and their means of production is given below:

Energy (keV)	Isotope/Origin	Remarks
53.4	^{73m}Ge	^{72}Ge (n,γ)
66.7	^{73m}Ge	^{72}Ge (n,γ) (sum 13.3 & 53.4 keV)
139.7	^{75m}Ge	^{74}Ge (n,γ)
198.4	^{71m}Ge	^{70}Ge (n,γ) (sum 174.9 & 23.4 keV
511	Positron ann.	Doppler broadened
569.7	^{207}Pb (n,n')	Originating from stable Pb in shield
595.8	^{74}Ge (n,n')	Broad assymetric, due to recoil summation
669.6	^{63}Cu (n,n')	
691.0	^{72}Ge (n,n')	Broad assymetric, due to recoil summation
803.1	^{206}Pb (n,n')	Originating from stable Pb in shield
834.0	^{72}Ge (n,n')	Broad assymetric, due to recoil summation
962.1	^{63}Cu (n,n')	
2614.5	^{208}Tl	Intensity about 0.1% of that of unshielded detector-believed to be shield penetration

Note: The fast and thermalised neutrons are of cosmic origin.



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CANBERRA

Ultra Low-Background Cryostats (ULB)

Features

- Low background materials
- No-stream-path design
- Offset preamplifier and adsorber
- Standardized hardware
- Uncompromised reliability

Description

CANBERRA has years of experience in building custom low-background detectors for low level gamma spectroscopy. The most important features of these custom detectors have been incorporated into standardized cryostat designs which can be produced quickly and economically and which produce predictable results. There are two basic Ultra Low-Background cryostat designs available, a vertical dipstick and a U-style integral. Both have the following design and construction features in common:

1. Low background materials are used for detector chamber, holder, and internal hardware.
2. Design offsets are used to allow the use of shielding materials between the detector element and hotter materials such as the preamplifier and adsorber (molecular sieves).
3. Direct streaming paths for external (to shield) sources of radiation are eliminated.
4. Materials having high cross-section for cosmic neutrons are avoided in construction.
5. Designs do not compromise ease of use or long-term reliability.

Among the select materials used in CANBERRA ULB cryostats are the following:

- Aluminum – 99.999% pure with guaranteed thorium and uranium less than 1 ppb.
- Copper – 99.99% pure (better than standard OFHC grade).
- Stainless Steel – selected low ^{60}Co content.
- Composite Carbon – Virtually zero background substitute for Be in low energy and wide range detectors.

A thorough discussion of low background detectors and systems can be found in CANBERRA's "Ultra Low-Background Detector Systems" Application Note. Ordering information is given below:

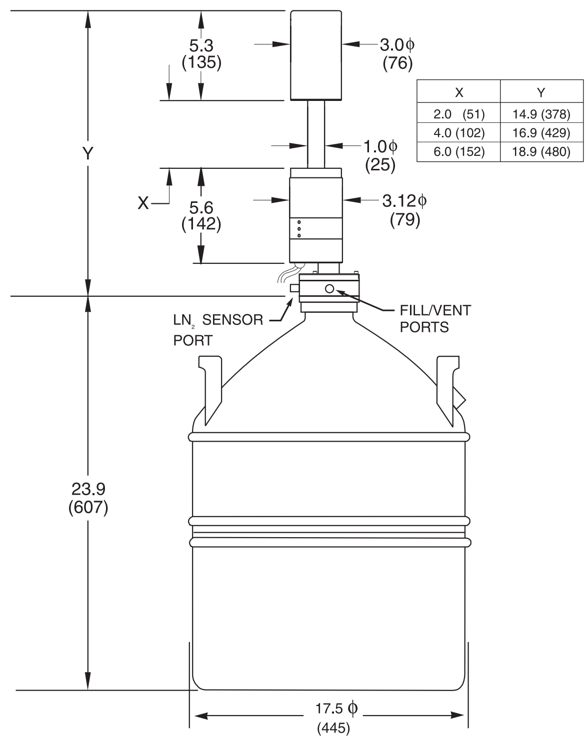
Model List for Ultra Low-Background Cryostat Option:		
Cryostat Type	**Dipstick**	**U-Style Integral**
Cryostat Model	7500SL	7915-30
Remote Detector Chamber	RDC-X*	N.A.
*X = 2, 4, or 6 for 2 inch, 4 inch or 6 inch neck.		

Ultra Low-Background Cryostats

Material (Choose one of the following):	
Detector Type	**Hardware Option**
Standard Electrode Coax	ULB-GC
Reverse Electrode Coax	ULB-GR
Extended Range Coax	ULB-GX
Low Energy	ULB-GL
Well Detector	ULB-GW
Broad Energy	ULB-GB

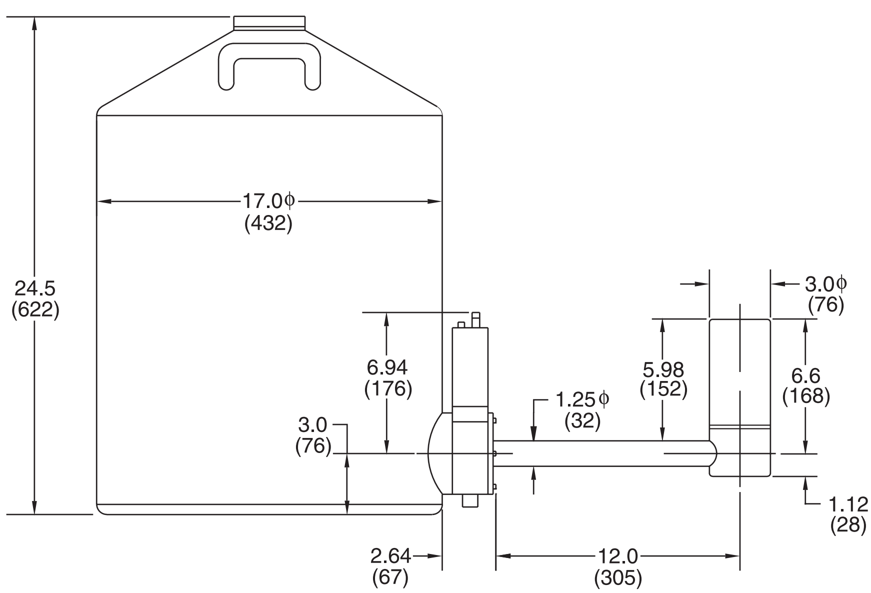
End cap dimensions depend on detector size. The chart below shows the typical efficiency range vs. end-cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end-cap size is critical in your application.

Rel. Efficiency (%)	Diameter in. (mm)
≤40	3.0 (76)
40-50	3.25 (83)
50-70	3.50 (89)
70-100	3.75 (95)
≥100	4.0 (102)



X	Y
2.0 (51)	14.9 (378)
4.0 (102)	16.9 (429)
6.0 (152)	18.9 (480)

Base Model 7500 SL



Base Model 7915-30

CANBERRA

U-Style Cryostats

CANBERRA U-Style cryostats have a vertically-oriented detector chamber located at the end of a horizontal arm extending from the side of the Dewar or cooler.

This configuration excludes the preamplifier and other hardware from the inner cavity of the lead shield and eliminates all line-of-sight streaming paths to the detector element. These features contribute significantly to the overall background reduction of the counting system.

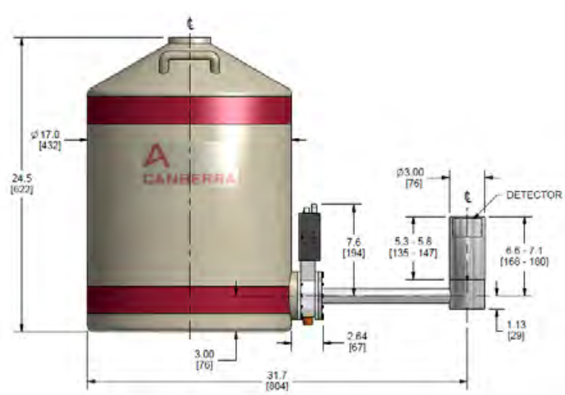
The U-Style configuration has a lower center of gravity for the detector and shield as compared to a standard vertical configuration which may make it attractive for mobile applications as in trailer- or ISO container-based counting facilities. Additionally the U-style configuration allows installing the detector in systems where there is no room under the shield to place the Dewar or cooler.

The standard length of the horizontal arm is 12 in. (305 mm) measured from the flange of the preamplifier service body to the detector center line. This length makes the U-style cryostat compatible with both 4 in. (102 mm) and 6 in. (152 mm) thick CANBERRA lead shields.

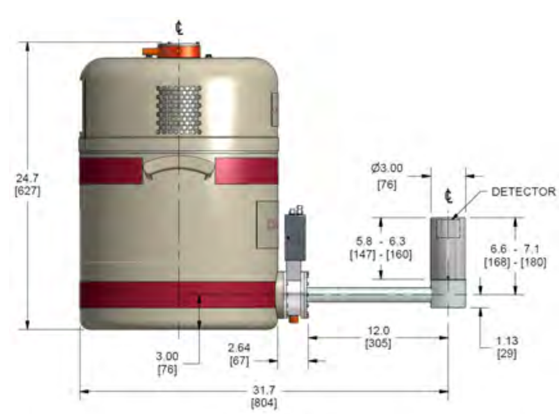
The standard configuration comes with a radial O-ring seal. A metal face seal is available as an option on detectors with a 3.0 in. (76 mm) diameter endcaps only. Metal seals are more rugged and, in general, provide a longer life time of the detector vacuum.

End cap dimensions depend on detector size. The chart below shows the typical efficiency range vs. end-cap diameter. End cap lengths are also greater for larger detectors. Consult the factory if end-cap size is critical in your application.

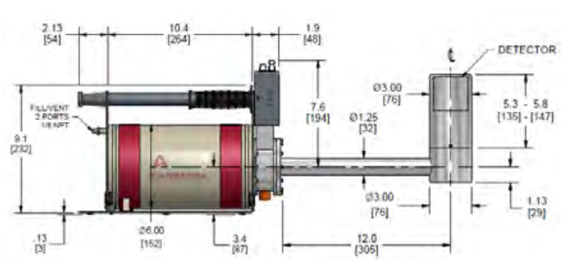
Rel. Efficiency (%)	Diameter in. (mm)
≤40	3.0 (76)
40-50	3.25 (83)
50-70	3.50 (89)
70-100	3.75 (95)
≥100	4.0 (102)



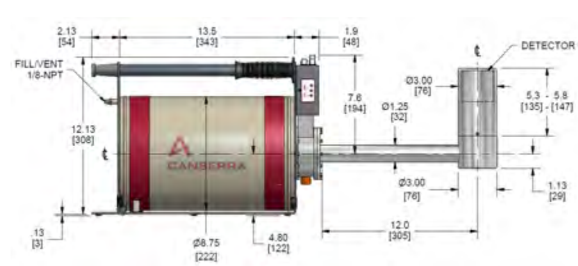
7905-30U Horizontal Integral Cryostat (also available in 7.5 and 15 liter version)



CCII-HI-U Horizontal Integral Hybrid Cryostat

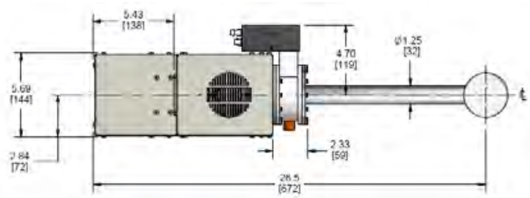


7935-2U Portable Multi-Attitude Cryostat (2 liter MAC)

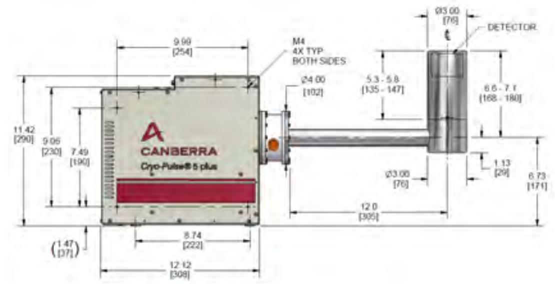


7935-7U Portable Multi-Attitude Cryostat (7 liter Big MAC)

U-Style Cryostats



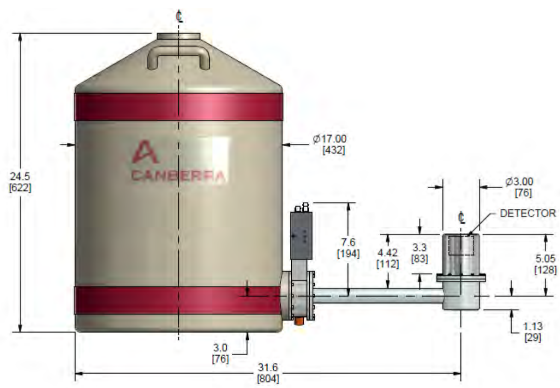
CP5-PLUS-U Electrically-Cooled Cryostat
(top view – preamplifier can be oriented in
other directions upon request)



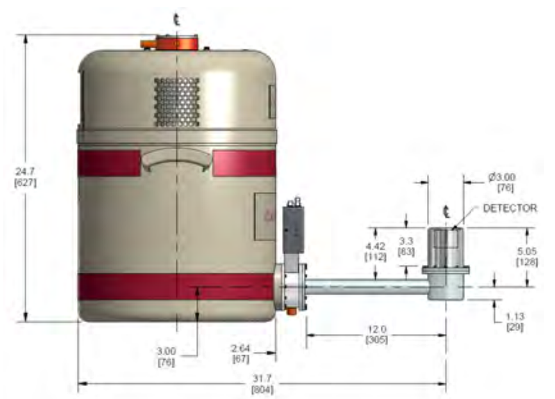
CP5-PLUS-U Electrically-Cooled Cryostat (side view)

Metal Seal U-Style Cryostats

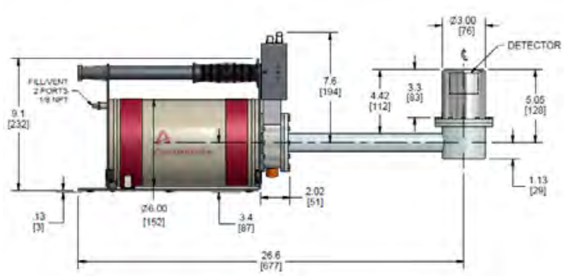
(available on 3 in. (76 mm) diameter endcaps only)



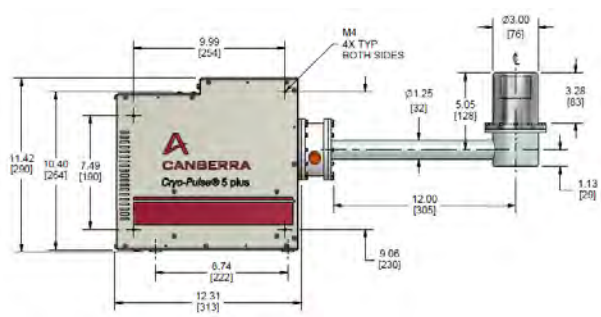
7905-30UM Horizontal Integral Cryostat
(also available in 7.5 and 15 liter version)



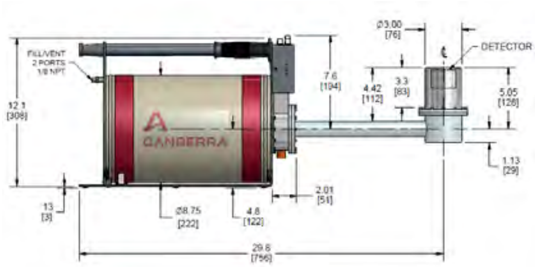
CCII-HI-UM Horizontal Integral
Hybrid Cryostat



7935-2UM Portable Multi-Attitude
Cryostat (2 liter MAC)

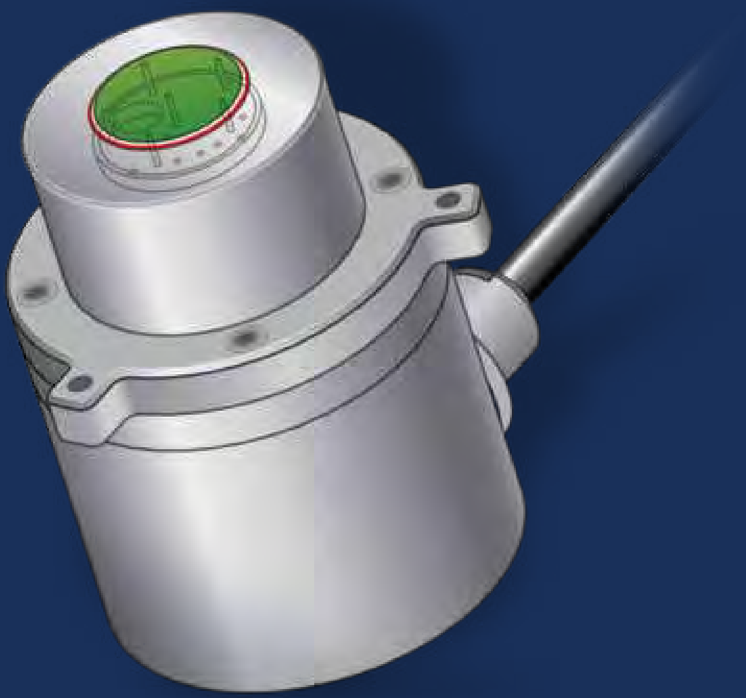


CP5-PLUS-UM Electrically-Cooled Cryostat (side view)



7935-7UM Portable Multi-Attitude
Cryostat (7 liter Big MAC)

SIMPLIFYING
Thermal Conductivity (*k*)



FAST, ACCURATE TESTING
0 to 500 W/mK in seconds

WIDE TEMPERATURE RANGE
-50˚ to 200˚C

NO SAMPLE PREPARATION
Unlimited sample size

NON-DESTRUCTIVE
Leaves sample intact

EASY-TO-USE
No user-calibration required

HIGHLY VERSATILE
Tests solids, liquids, powders and pastes

MODULAR
Configurable to meet a range of needs and budget
Option to pair with new dilatometer

C-THERM TCi™
Thermal Conductivity Analyzer

ALSO PROVIDES: EFFUSIVITY | DIFFUSIVITY | HEAT CAPACITY | DENSITY

SIMPLIFYING

THERMAL CONDUCTIVITY

The latest generation of C-Therm's patented technology expands the capabilities of this rapid, non-destructive thermal conductivity and effusivity testing instrument to a whole new level. Designed to provide simple, highly accurate thermal characterization for lab, quality control and production environments, the C-Therm TCi Thermal Conductivity Analyzer requires no user-calibration or sample preparation. The system has broad testing capabilities (0 to 500W/mK) across a wide range of temperatures (-50ºC to 200ºC).

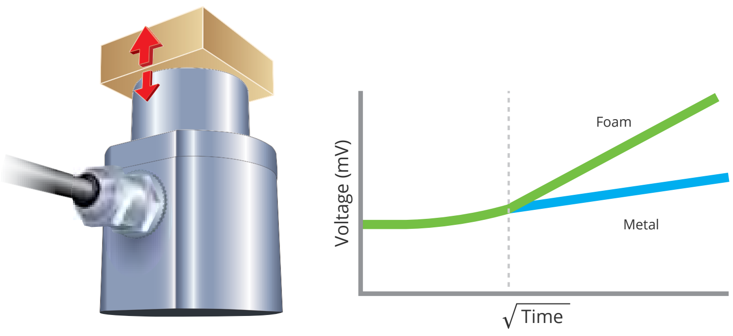
The TCi can be equipped with one or two sensors for increased capacity, and provides accurate thermal analysis of solids, liquids, powders and pastes in less time than any other instrument - less than 5 seconds! And because the procedure is non-destructive, samples remain intact, undisturbed and reusable after testing. The sensors offer users exceptional versatility in being able to operate in various environments, including thermal chambers, high pressure vessels and glove boxes.

Principles of Operation

The C-Therm TCi is based on the Modified Transient Plane Source (MTPS) technique. It employs a one-sided, interfacial heat reflectance sensor that applies a momentary constant heat source to the sample. Thermal conductivity and effusivity are measured directly, providing a detailed overview of the thermal characteristics of the sample.

How It Works

A known current is applied to the sensor's spiral heating element, providing a small amount of heat. This results in a rise in temperature at the interface between sensor and sample, which induces a change in the voltage drop of the sensor element. The rate of increase in the sensor voltage is used to determine the thermo-physical properties of the sample. The thermo-physical properties are inversely proportional to the rate of increase in the sensor voltage. The voltage rise will be steeper for more thermally insulative materials (foam). Results are displayed on the system's software in real-time.



The TCi is factory-calibrated for directly measuring both thermal conductivity (k) & thermal effusivity:

$$k \quad \& \quad \text{Effusivity} = \sqrt{k \rho c_p}$$

Where:

k = thermal conductivity (W/m • K)

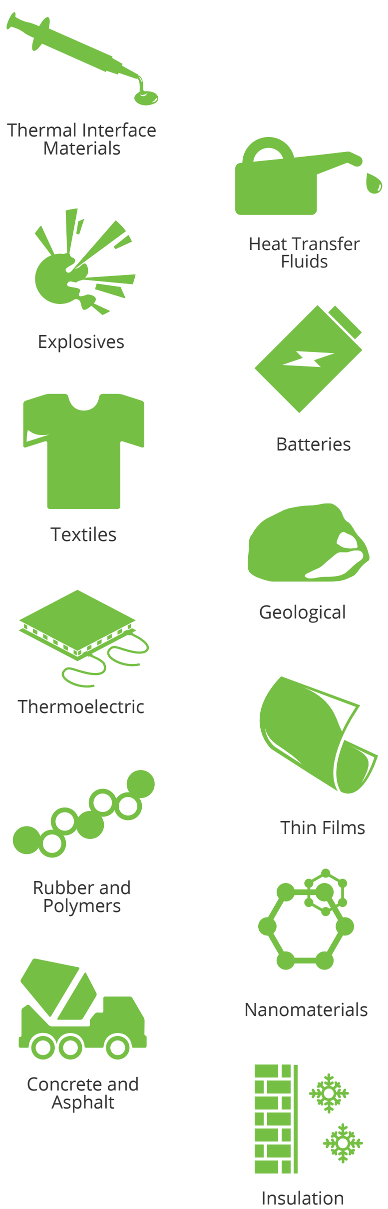
ρ = density (kg/m^3)

c_p = heat capacity (J/kg • K)

VERSATILE

EASILY TEST SOLIDS, LIQUIDS, POWDERS AND PASTES

APPLICATIONS



Solids: Taking Ceramics to New Heights

C-Therm has provided a breakthrough in the characterization of critical performance attributes of ceramics used for aerospace applications. The main advantage for solids applications is the simplicity of the sample format. The C-Therm TCi eliminates technician time required for sample preparation. The sample size flexibility allows the evaluation of actual product formats - avoiding the need to mock-up samples.

Powders: From Explosives to Ink Toners

The C-Therm TCi is being used to safely test the stability, degradation, and shelf life of explosives because it is the only instrument engineered for evaluating the thermal conductivity of powders safely. Sample volumes are as small as 1.85ml. This is also critical to a rapidly growing client base in metal hydrides, where materials are expensive and available in low quantities. The technology is also migratable to manufacturing environments as a cost-effective way to monitor powder processes for moisture and homogeneity.

Pastes: Keeping the Hottest Electronics Cool

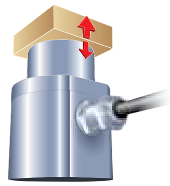
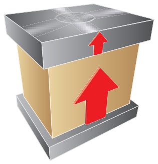
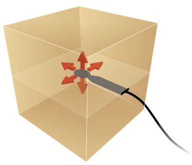
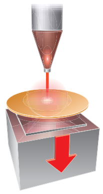
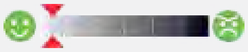
The faster and smaller microprocessors become, the more heat they generate. C-Therm technology is providing vital insights into the development of all materials that contribute to the overall thermal budget, including thermal interface pastes and compounds. By altering the calibration timing parameters the C-Therm TCi allows testing with different amounts of heat penetration. This feature results in a variable scale of scrutiny to probe the material to ensure the homogeneous distribution of vital filler components.

Liquids: Fluids That Take the Heat Off

The C-Therm TCi is helping manufacturers improve the heat transfer properties of advanced nano-filled liquids. For engineered liquids, the wide range of operating temperatures make the TCi an attractive solution. The low amount of heat introduced during testing and small sample volume requirements negate the convective errors typical in liquid testing with traditional techniques.

COMPARISON OF METHODS

FASTER, EASIER, MORE VERSATILE

	 C-Therm TCi (Modified Transient Plane Source)	 Traditional Guarded Hot Plate	 Transient Plane Source	 LaserFlash Diffusivity
SPEED & FLEXIBILITY				
Sample Preparation	None Required	Extensive	Some	Extensive
Testing Time	Seconds	Hours	Minutes	Hours*
Training Time	Minimal	Moderate	Significant**	Extensive
Non-Destructive	Yes	No	No	No
Method Development				
RANGE				
k-Range (W/mK)	0 – 500	0 – 2	0 – 100 (100 – 500 requires C_p)	0 – 500 (requires density & C_p)
Temperature Range (ºF) (ºC)	-58º to 392ºF -50º to 200ºC	-148º to 2552ºF -100º to 1400ºC	-148º to 1292ºF -100º to 700ºC	-238º to 5072ºF -150º to 2800ºC
SAMPLE CONFIGURATION				
Minimum	0.67" diameter (17mm)	6" x 6" (150 x 150mm)	Two Identical Samples 1" x 1" (25 x 25mm)	0.5" diameter (12.4mm) 0.004" thick (1mm)
Maximum	Unlimited	24" x 24" (600 x 600mm)	Two Identical Samples Unlimited	0.5" diameter (12.4mm) 0.004" thick (1mm)
Material Testing Capabilities	Solids, Liquids, Powders, Pastes	Solids	Solids, Liquids	Solids
PRICING	$	$ $	$ $	$ $ $

1 Based on publicly available information and feedback from users.

* Calculation of thermal conductivity from Laser Flash Diffusivity Measurement requires the additional following material properties: heat capacity (C_p) density, and coefficient of thermal expansion.

** Traditional Transient Plane Source requires iterative testing to obtain the correct experimental parameters in terms of power flux, test time, and sizing of sensor necessary to obtain accurate results.

MODULAR

SCALABLE SOLUTIONS

ACCESSORIES

Compression Test Accessory (CTA)

Compression of sample material increases the density and impacts the effective thermal conductivity of the material. C-Therm's Compression Test Accessory (CTA) enables researchers testing such materials to precisely control the densification in providing highly reproducible results that better reflect the effective thermal conductivity of the sample material. The CTA is particularly recommended to users testing textiles/fabrics, insulation batting, thermal interface materials, and powders.

High Pressure Cell (HPC)

The High Pressure Cell safely provides researchers the capability to characterize the thermal conductivity of samples under controlled pressure environments up to 2,000 PSI (~138 bar). The HPC is popular with researchers in the energy field, particularly in the characterization of gas hydrates.

Tenney Jr. Thermal Chamber

The TPS Tenney Jr. Thermal Chamber is recommended to users who wish to measure the thermal conductivity at non-ambient temperatures, from -50ºC to 200ºC. C-Therm's TCi 3.0 release software now enables direct control of the thermal chamber, bypassing manual operation and allowing users to pre-program their desired temperature cycles and walk away!

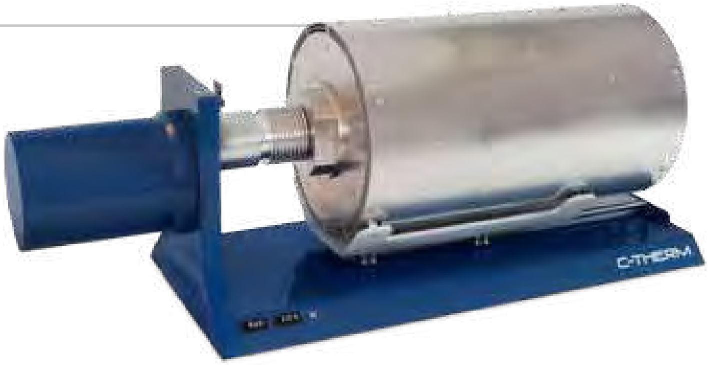
Small-Volume Test Kit (SVTK)

The Small-Volume Test Kit was originally developed with the US Navy specifically for testing energetic materials. The effectiveness of the accessory in reducing the volume requirements for testing samples make it ideal for characterizing the thermal conductivity of liquid samples. The SVTK is commonly applied in testing nano and heat transfer fluids, as well as emulsions.

DILATOMETRY MODULE

Dilatometry provides key expansion and shrinkage properties of materials under defined temperatures.

TEMPERATURE RANGE	Room Temperature to 1600°C
TEMP. RESOLUTION	0.1°C
MAX DISPLACEMENT	4mm
ΔI RESOLUTION	1.25nm/digit
ATMOSPHERE	Air, Vacuum, Inert Gas
SAMPLE DIMENSIONS	10 to 50mm long x max ϕ12mm
SAMPLE HOLDER	Fused Silica, Alumina
CONFIGURATIONS	Single or Dual LVDT System 1200°C or 1600°C furnace
HEATING ELEMENT	FeCrNi, SiCr
RATE OF INCREASE (ºC)	1ºC/min to 50ºC/min



C-Therm's latest generation TCi offers an innovative new option to pair the controller with an optional dilatometer. This offers researchers significant savings in leveraging commonalities of the TCi control electronics, while expanding the platform's capabilities to dilatometry.

THERMAL EXPANSION • PHASE TRANSITION
SHRINKAGE • SINTERING

PROVEN

For over a decade, C-Therm's innovative sensor technology has been pioneering the way many of the world's most prominent manufacturers, research facilities, and academic institutions test and measure thermal properties of materials.

The technology behind the C-Therm TCi represents a paradigm shift in thermal conductivity measurement and earned the inventor behind the technology the Manning Innovation Principle Award and an R&D 100 Award. These coveted awards are given to the top global innovators, and place C-Therm in the distinguished company of other winners, including developers of the ATM, Polaroid film, and anti-lock brakes.

Since its launch, C-Therm's unique technology has evolved to new levels of accuracy, speed, and flexibility. Today, it is being used around the globe for R&D, quality control, and on-line production monitoring in a wide range of industries.

C-THERM TCI SPECIFICATIONS	
Thermal Conductivity Range	0 to 500 W/mK
Test Time	0.8 to 2.5 seconds
Minimum Sample Testing Size	17mm (0.67") diameter
Maximum Sample Testing Size	Unlimited
Minimum Thickness	Nominally 0.02" (0.5mm), dependent on thermal conductivity of material
Maximum Thickness	Unlimited
Temperature Range	-50° to 200°C (-58° to 392°F)
Precision	Typically better than 1%
Accuracy	Better than 5%
Extra Hook-Ups Required	None
Software	Intuitive Windows®-based software interface. Easy export to Microsoft Excel®. Additional functionality offers indirect, user-input capabilities for a number of other thermo-physical properties including: • Thermal Diffusivity • Heat Capacity • Density
Input Power	110-230 VAC 50-60 Hz
Certifications	FCC, CE, CSA

For more information, contact:

C-THERM TECHNOLOGIES Ltd.

North America: 1-877-827-7623
Worldwide: 1-506-462-7201
info@ctherm.com | www.ctherm.com

COMPANIES AND ORGANIZATIONS USING C-THERM'S PATENTED TECHNOLOGY:

IBM
Whirlpool
Pioneer
General Electric
Kodak
Avery
3M
Philip Morris
Astra Zeneca
US Navy
Patheon
Universidade de Aveiro
Raytheon
Corning
Engelhard
Universidade Federal de Santa Caterina
Wyeth
Stowe Woodward
INSA
Dow Corning
Exxon Mobil
Hewlett Packard
NRC
Liberec University
National University of Singapore
Petrobas
Henkel
Nanocomposix
Canadian Explosives Research Lab

FLIR GF306 Infrared Cameras

SF6 Detection and Electrical Inspections

The FLIR GF306 detects and visualizes SF6 (Sulfur Hexafluoride) and 25 other harmful gases quickly from a safe distance and without the need to interrupt your plant's production process.

SF6 is a gas used in electrical substations at electric power plants as an insulator in circuit breakers and switchgear. The gas is also used in magnesium production and semiconductor manufacturing. SF6 is harmful to the environment. It has a global warming potential 24,000 times higher than CO2 emissions - more than any other greenhouse gas. Early detection and repair of leaks is a contribution of electric power plants to protect the environment.

Key Features

- Visualize gas leaks in real time
- Fully calibrated for temperature measurement applications
- Embedded GPS data in reporting
- Inspect without interruption of process
- Considerably reduce inspection time
- Trace leaks to source
- Spot leaks close by or meters away
- Verification of repair

Makes Reporting Easy

Images from FLIR GF-Series infrared cameras are recordable to any off-the-shelf video recorder for easy archiving and documentation.

Gases Detected

The FLIR GF306 infrared camera can detect the following gases:

- SF6 (Sulfur Hexaflouride) - 0.026g/hr
- Acetic Acid (C2H4O2)
- Anhydrous Ammonia (NH3)
- Chlorine Dioxide (ClO2)
- Dichlorodifluoromethane "FREON-12" (CCl2F2)
- Ethyl Cyanoacrylate "Superglue" (C6H7NO2)
- Ethylene (C2H4)

Specifications

Model Number	GF306
Imaging Specifications	

Detector Type	Cooled QWIP
Spectral Response	10.3 – 10.7 µm
Resolution	320 × 240
Total Pixels	76,800
Thermal Sensitivity	<15 mK @ +30°C (+86°F)
Accuracy	±1°C (±1.8°F) for temperature range 0°C to +100°C (+32°F to +212°F) or ±2% of reading for temperature range >+100°C (>+212°F)
Temperature Range	-40°C to 500°C (-40°F to 932°F)
High Temp Option	Not Available
Lens Options	Standard 14.5° × 10.8°; Optional: 24°
Zoom	1 – 8× continuous digital
Focus	Auto & Manual
Color LCD	4.3"; 800 × 480 Pixels
Adjustable Viewfinder	Tiltable OLED, 800 × 480 pixels
Video Camera w/Lamp	3.2 MP
Laser Spot	Yes
Video Out	HDMI
Analysis	
Spotmeters	10
Area Boxes	5 (min./max./avg.)
Profiles	1 live line (horiz. or vert.)
Delta T	Yes
Annotation	
GPS	Yes
File Storage	
Radiometric JPG	Yes
Radiometric Video (15Hz)	No

MPEG Video Recording	Yes

GF306 Videos

Watch the videos below to see footage taken with the FLIR GF306.

Product Documents

FLIR GF-Series Brochure (http://www.flirmedia.com/MMC/THG/Brochures/T820433/T820433_EN.pdf)
FLIR GF-Series - Fixed Lens Export Information (http://www.flir.com/uploadedFiles/Thermography_Americas/Service_and_Support/GF%20Series%20fixed%20lens.pdf)
FLIR GF-Series - Removable Lens Export Information (http://www.flir.com/uploadedFiles/Thermography_Americas/Service_and_Support/GF%20Series%20removable%20lens.pdf)

Articles

Oil and Gas Industry Faces Its Methane Problem (http://news.nationalgeographic.com/news/energy/2014/12/141211-oil-gas-methane-leaks-epa-rules/)
National Geographic

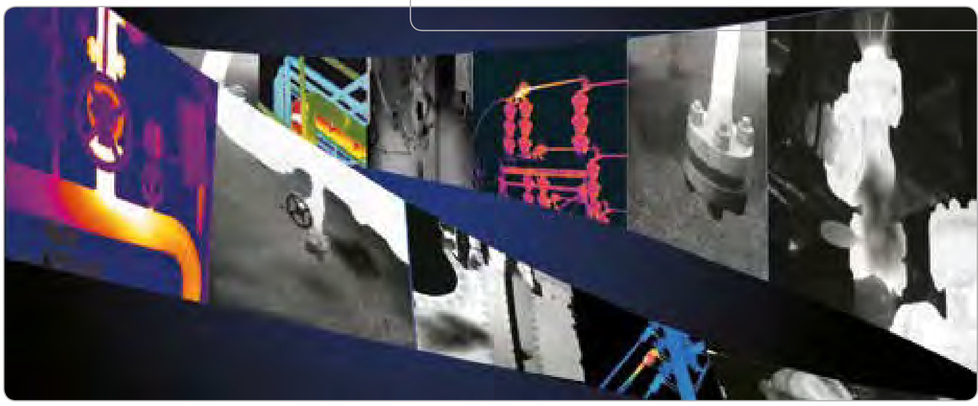
Delaware-size gas plume over West illustrates the cost of leaking methane (http://www.washingtonpost.com/national/health-science/delaware-sized-gas-plume-over-west-illustrates-the-cost-of-leaking-methane/2014/12/29/d34c3e6e-8d1f-11e4-a085-34e9b9f09a58_story.html)
Washington Post

Reports

Clean Air Task Force is a nonprofit organization dedicated to reducing atmospheric pollution through research, advocacy, and private sector collaboration. Read more (http://www.catf.us/resources/publications/files/WasteNot.pdf)

Carbon Limits (formerly ECON Carbon), based in Oslo, Norway, is an active player in energy efficiency and greenhouse gas emission reduction projects. With substantial experience in all the aspects of carbon markets and climate policy, Carbon Limits assists clients in identifying, developing, and monitoring emission reduction projects. Read more

Thermal imaging cameras for optical gas imaging (OGI) and furnace inspections



Detect gas leaks

Protect the environment

See through flames

Increase safety

FLIR GF306

Optical gas imaging especially of SF_6 and ammonia

The FLIR GF306 visualizes and pinpoints gas leaks of SF_6 and ammonia, without the need to de-energize high-voltage equipment or shut down the operation. The portable camera also greatly improves operator safety, by detecting emissions at a safe distance, and helps to protect the environment by tracing leaks of environmentally harmful gases.

SF_6 is used in the electric power industry as an insulator and quenching medium for gas-insulated substations and circuit breakers. Ammonia is produced in ammonia plants, and is used mainly for the production of fertilizers.

Cooled detector
The FLIR GF306 contains a cooled Quantum Well Infrared Photodetector (QWIP). This highly sensitive detector visualizes gases in the 10.3 – 10.7 micrometer waveband. It will not only make gases, but also the smallest of temperature differences, clearly visible.

Temperature range
The FLIR GF306 visualizes temperatures from -40°C to +500°C.

Dual use
The FLIR GF306 can be used both for finding gas leaks and maintenance inspections.

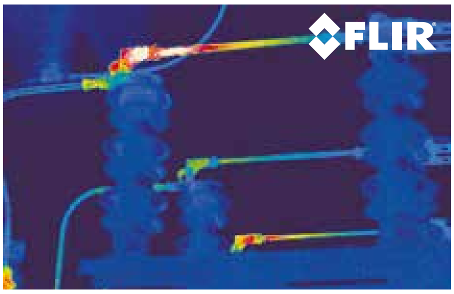
Available lenses
The FLIR GF306 comes either with a fixed 14.5° lens or with a fixed 24° lens. A version with interchangeable lenses is also available but requires a US Department of State license.

The FLIR GF306 detects the following gases:

- Sulfur Hexafluoride (SF_6)
- Acetyl Chloride
- Acetic Acid
- Allyl Bromide
- Allyl Chloride
- Allyl Fluoride
- Ammonia (NH_3)
- Bromomethane
- Chlorine Dioxide
- Ethyl Cyanoacrylate
- Ethylene
- Furan
- Hydrazine
- Methylsilane
- Methyl Ethyl Ketone
- Methyl Vinyl Ketone
- Propenal
- Propene
- Tetrahydrofuran
- Trichloroethylene
- Uranyl Fluoride
- Vinyl Chloride
- Vinyl Cyanide
- Vinyl Ether

Industries:

Petrochemical & chemical industries



Electrical Utility

Captured SF_6 leak

FLIR GF304 / GF306 / GF320 / GF346

Technical specifications

Camera specific

	GF304	GF306	GF320	GF346
Imaging and optical data				
Focal Plane Array (FPA) / Spectral range	Cooled QWIP / 8.0–8.6 µm	Cooled QWIP / 10.3–10.7 µm	Cooled InSb / 3.2–3.4 µm	Cooled InSb / Built-in cold band pass filter 4.52 - 4.67 µm
Measurement				
Accuracy	±1°C for temperature range (0-100 °C) or ±2% of reading for temperature range (> +100 °C)	±1°C for temperature range (0-100 °C) or ±2% of reading for temperature range (> +100 °C)	±1°C for temperature range (0-100 °C) or ±2% of reading for temperature range (> +100 °C)	+/- 1 °C or +/- 1% of reading for temperature range 0° C to +300 °C
Measurement range	-20°C to +500°C	-40°C to +500°C	-40°C to +350°C	-20°C to +300°C
Power system				
Battery operating time	> 3 hours at 25°C and typical use	> 2 hours at 25°C and typical use	> 3 hours at 25°C and typical use	> 3 hours at 25°C and typical use
Start-up time	Typically 8 min. @ 25°C	Typically 10 min. @ 25°C	Typically 7 min. @ 25°C	Typically 7 min. @ 25°C
Environmental data				
Operating temperature range	–20°C to +40°C	–20°C to +40°C	–20°C to +50°C	–20°C to +50°C
Gas detection				
Gases	• R404A • R407C • R410A • R134A • R417A • R422A • R507A • R143A • R125 • R245fa	• Sulfur Hexafluoride (SF_6) • Acetyl Chloride • Acetic Acid • Allyl Bromide • Allyl Chloride • Allyl Fluoride • Ammonia (NH3) • Bromomethane • Chloride Dioxide • Ethyl Cyanoacrylate • Ethylene • Furan • Hydrazine • Methylsilane • Methyl Ethyl Ketone • Methyl Vinyl Ketone • Propenal • Propene • Tetrahydrofuran • Trichloroethylene • Uranyl Fluoride • Vinyl Chloride • Vinyl Cyanide • Vinyl Ether	• Benzene • Ethanol • Ethylbenzene • Heptane • Hexane • Isoprene • Methanol • MEK • MIBK • Octane • Pentane • 1-Pentene • Toluene • Xylene • Butane • Ethane • Methane • Propane • Ethylene • Propylene	• Acetonitrile • Acetyl cyanide • Arsine • Bromine isocyanate • Butyl isocyanide • Carbon monoxide • Chlorine isocyanate • Chlorodimethylsilane • Cyanogen bromide • Dichloromethylsilane • Ethenone • Ethyl thiocyanate • Germane • Hexyl isocyanide • Ketene • Methyl thiocyanate • Nitrous oxide • Silane

Automatic (one Touch) and Manual Focus w/ 1 to 8 Continuous Digital Zoom helps you to deliver the perfect picture at ease.

Tiltable, flip-out 4.3" High Contrast Color LCD allows you to view targets more safely from any angle.

General specifications

Imaging and optical data	
Field of view (FOV) / Minimum focus distance	14.5º lens: 14.5º x 10.8º / 0.5m 24º lens: 24° × 18° / 0.3 m
F-number	1.5
Focus	Automatic (one touch) or manual (electric or on the lens)
Zoom	1–8× continuous, digital zoom
Digital image enhancement	Noise reduction filter, High Sensitivity Mode (HSM)
IR resolution	320 × 240 pixels
Thermal sensitivity / NETD	<15 mK @ +30°C
Sensor cooling	Stirling Microcooler (FLIR MC-3)
Electronics and data rate	
Full frame rate	60 Hz
Image presentation	
Display	Built-in widescreen, 4.3 in. LCD, 800 × 480 pixels
Viewfinder	Built-in, tiltable OLED, 800 × 480 pixels
Automatic image adjustment	Continuous/manual; linear or histogram based
Manual image adjustment	Level/span
Image modes	IR-image, visual image, High Sensitivity Mode (HSM)
Measurement analysis	
Spotmeter	10
Area	5 boxes with max./min./average
Profile	1 live line (horizontal or vertical)
Difference temperature	Delta temperature between measurement functions or reference temperature
Reference temperature	Manually set or captured from any measurement function
Emissivity correction	Variable from 0.01 to 1.0 or selected from editable materials list
Measurement corrections	Reflected temperature, distance, atmospheric transmission, humidity, external optics
Set-up	
Menu commands	Level, span Auto adjust continuous/manual/semi-automatic Zoom Palette Start/stop recording Store image Playback/recall image
Color palettes	Iron, Gray, Rainbow, Arctic, Lava, Rainbow HC
Set-up commands	1 programmable button, overlay recording mode, local adaptation of units, language, date and time formats
Storage of images	
Image storage type	Removable SD or SDHC Memory Card, two card slots
Image storage capacity	> 1200 images (JPEG) with post process capability per GB on memory card
Image storage mode	IR/visual images Visual image can automatically be associated with corresponding IR image
Periodic image storage	Every 10 seconds up to 24 hours
File formats	Standard JPEG, 14 bit measurement data included
GPS	Location data automatically added to every image from built-in GPS
Video recording and streaming	
Non radiometric IR-video recording	MPEG4 (up to 60 minutes/clip) to memory card. Visual image can automatically be associated with corresponding recording of non radiometric IR-video.
Visual video recording	MPEG4 (25 minutes/clip) to memory card
Radiometric IR-video streaming	Full dynamic to PC using USB or WLAN
Non radiometric IR-video streaming	RTP/MPEG4
Visual video streaming	MPEG4 using Wi-Fi Uncompressed colorized video using USB
Digital camera	
Built-in digital camera	3.2 Mpixel, auto focus, and two video lamps
Laser pointer	
Laser	Activated by dedicated button
Data communication interfaces	
WLAN	Peer to peer (adhoc) for iOS or infrastructure (network) for Android
USB	USB-A: Connect external USB device (e.g. memory stick) USB Mini-B: Data transfer to and from PC
USB, standard	USB Mini-B: 2.0 High Speed
Video	Digital Video Output (image)
Power system	
Battery type	Rechargeable Li Ion battery
Battery voltage	7.2 V
Charging system	In camera (AC adapter or 12 V from a vehicle) or 2-bay charger
Environmental data	
Storage temperature range	–30°C to +60°C
Humidity (operating and storage)	IEC 68-2-30/24 h 95% relative humidity +25°C to +40°C (2 cycl)
EMC	EN61000-6-4 (Emission) EN61000-6-2 (Immunity) FCC 47 CFR Part 15 class A (Emission) EN 61 000-4-8, L5
Encapsulation	IP 54 (IEC 60529)
Bump	25 g (IEC 60068-2-29)
Vibration	2 g (IEC 60068-2-6)
Physical data	
Camera weight, incl. lens and battery	2.48 kg
Battery weight	0.24 kg
Cameras size, incl. lens (L × W × H)	306 × 169 × 161 mm
Tripod mounting	Standard, ¼"-20
Housing material	Aluminium, Magnesium
Grip material	TPE Thermoplastic Elastomers

Scope of delivery

Thermal imaging camera, Hard transport case, Battery charger, Battery, 2 ea., Calibration Certificate, Downloads brochure, FLIR Tools PC software CD-ROM, FLIR VideoReport™ PC software CD-ROM, HDMI-DVI cable, HDMI-HDMI cable, Lens cap (mounted on lens), Memory card, Memory card adapter, Power supply, incl. multi-plugs, Printed Getting Started Guide, Printed important information guide, Registration card, Service & training brochure, Shoulder strap, USB cable, User documentation CD-ROM, Wi-Fi USB micro-adapter (depending on CE and FCC regulations regarding wireless equipment for your country)

Note: These specifications are for GF-Series with a fixed 14.5º or 24º lens.
Versions with an interchangeable lens are also available but these require a US Department of State Export license.

SPECIFICATIONS

FOR

0.4W INTEGRAL STIRLING CRYOCOOLER

MODEL SCI04R

SPECIFICATION: 04RJS0101（ISSUE B）

2014-04-08

Specifications are subject to change without notice.

1 SCOPE

This specification and acceptance test procedure describes the technical performance, quality guaranty and delivery requirements for a miniature Stirling cycle system to be used to cool an infrared detector to cryogenic temperatures. This cooler design model is solidly based on the concepts of direct detector mounting on the cooler's cold finger, and integral construction of cooler and Dewar envelope. The cooler contains an onboard temperature controller and driven by a DC brushless motor.

2 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of the specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1 Government Documents

GJB150.1-1986 Environmental test methods for military equipments, General.

GJB151A-1997 Electromagnetic emission and susceptibility requirements for military equipment and subsystems.

GJB152A-1997 Measurement of electromagnetic emission and susceptibility for military equipment and subsystems.

GJB899-1990 Reliability test for qualification and production acceptance

2.2 K.I.P. Documents

SCI04R Specifications 04RJS0101 ISSUE G

3 REQUIREMENTS

3.1 Size

The configuration of the cooler confirm to the outline specified in ANNEX 1.

3.2 Electrical Connectors

All connectors used external the cooler shall be in accordance with ANNEX 2.
The function of these pins used connectors confirm to the Table1.

Table 1 Function of pins used connectors

Pin No	Function	Sign
1	Temperature Sensor Diode（- negative）	D-
2	Shut down	SWN
3	Stand By	STBY
4	Power Supply（- negative）	V-
5	Cool Down Indication	CD
6	Temperature Sensor Diode（- negative）	D+
7	No connect (test terminal only for manufacturer)	NC
8	Power Supply（+ positive）	V+
9	Motor Case	Case

The cooler is designed to operate from a power supply of 24V_{DC}±1V_{DC}. The cooler shall provide 0.5mA±0.1mA to drive the temperature sensor at ambient temperature.

3.3 Weight

The weight of the cooler shall not exceed 470g. (Cold finger protect cover and dewar not included)

3.4 Workmanship

Coolers shall be processed in such a manner as to be uniform in quality and shall be free from defects that will affect their life, serviceability, interchangeability, or appearance.

3.5 Labeling and marking

All labeling and marking shall be clear and legible throughout all the tests specified herein. The cooler shall have a nameplate marked with the Stock Number, the manufacturer's part number, the filling pressure and the date of manufacture.

3.6 Performance characteristics

The cooler shall meet the performance characteristics specified herein when adequate heat sinking or convective cooling is provided to ensure that any point on the cooler cylinder head shall no higher than 10°C above ambient air temperature.

3.6.1 Refrigeration Controlling and Indication Functions

The cooler's B49 hybrid controller shall be accordance with 3.6.1.1 to 3.6.1.7 at 23℃ ±2℃ ambient temperature, according to 4.6.6 test procedure.

3.6.1.1 Steady-state Cooling Capacity

The operation mode temperature sensor voltage shall be 1.048V±0.002V (equivalent to 80K±1K).

3.6.1.2 Stand By MODE (SB MODE)

At this mode the temperature sensor voltage shall be 1.029V±0.010V.

3.6.1.3 Cool-down Indication

At the operation mode: The cool-down indication is activated when the temperature sensor reaches 1.044V±0.010V，and is deactivated when the temperature sensor reaches 1.043V±0.010V.

At the SB mode: The cool-down indication is activated when the temperature sensor reaches 1.025V±0.010V，and is deactivated when the temperature sensor reaches 1.024V±0.010V.

3.6.1.4 Shut Down Control

The cooler shall have a remote shut down capability that stops the motor voltage but leaves all other voltages unchanged, and which is activated by closing S2 as described in ANNEX 2.

3.6.1.5 Power Input

The cooler is designed to operate at a rated voltage of 24VDC±1VDC. And the cooler can operate from a power supply of 18VDC-28VDC.

3.6.1.6 Chassis Isolation

The cooler has a Chromatic Anodized coating, and shall be isolated (not less than 20MΩ).

3.6.1.7 Chassis Grounding

All external metalized surfaces of the cooler shall be electrically conductive to system chassis with a maximum resistance of 0.2 Ω.

3.6.2 Accuracy and Stability of Refrigeration Controlling and Indication Functions

The fluctuations of the cold tip temperature at the operation and SB modes and of the cool-down indication at any constant ambient temperature in the range of -40℃～+70℃ shall be less than ±2K(±0.0034V).

The deviation of the values at any ambient temperature in the range of -40℃～+70℃, from the values at ambient temperature 23℃±2℃ shall be less than ±3K (±0.0051V).

3.6.3 Cool-down Time

The maximum cool-down time to reach a cold tip temperature from ambient with a 250J±20J thermal mass (from 300K to 80K) shall be in accordance with：

a) The cool-down time to reach a cold tip temperature of 80K in a simulation dewar at 23℃±2℃ambient temperature shall be less than 7 minutes.
b) The cool-down time to reach a cold tip temperature of 80K in a simulation dewar at -40℃±2℃ambient temperature shall be less than 7 minutes.
c) The cool-down time to reach a cold tip temperature of 80K in a simulation dewar at +70℃±2℃ambient temperature shall be less than 9 minutes.

3.6.4 Cooling Capacity

The cooler shall provide the minimum refrigeration capacity in accordance with：

a) The additional added electrical heat load at 80K in a simulation dewar at 23℃ ±2℃ambient temperature shall be no less than 270mW.
b) The additional added electrical heat load at 80K in a simulation dewar at -40℃ ±2℃ambient temperature shall be no less than 320mW.
c) The additional added electrical heat load at 80K in a simulation dewar at+70℃ ±2℃ambient temperature shall be no less than 120mW.

3.6.5 Power Consumption

a) The power consumption at full speed operation mode at 23℃±2℃ambient temperature shall be less than 15W, the power consumption at steady operation mode shall be less than 9W(without additional added electrical heat load).
b) The power consumption at full speed operation mode at -40℃±2℃ambient temperature shall be less than 15W.
c) The power consumption at full speed operation mode at +70℃±2℃ambient temperature shall be less than 15W.

In the temperature range of -40℃～+70℃ and at any operation conditions, the power consumption of the cooler shall be less than 17W.

3.6.6 Leak rate

The leak rate of the cooler shall be less than 8×10^{-9} Pa·m^3/sec at an ambient temperature of 23℃±2℃.

3.6.7 Acoustic noise

The cooler noise emission shall be less than 50dB at an ambient temperature of 23℃±2℃.

3.6.8 Vibration output

The cooler Vibration output shall be less than 20m/s^2 at an ambient temperature of 23℃±2℃.

3.7 Environmental conditions

3.7.1 High temperature, operating

The cooler shall not be damaged by operation up to +70°C.

Temperature: +70°C ± 2°C
Duration: 30 minutes

3.7.2 High temperature, storage

The cooler shall not be damaged by storage to +85°C.

Temperature: +85°C ± 2°C
Duration: 48 hours

3.7.3 Low temperature, operating

The cooler shall not be damaged by operation to -40°C.

Temperature: -40°C ± 2°C

Duration: 30 minutes

3.7.4 Low temperature, storage

The cooler shall not be damaged by storage to -55°C.

Temperature: -55°C ± 2°C

Duration: 24 hours

3.7.5 Temperature Shock

The cooler shall not be damaged (see 6.3.1) by sudden changes in temperature between -55°C and +85°C.

3.7.6 Vibration

The cooler shall not be damaged after exposure to the follow environmental conditions in the 3 perpendicular axes:

a) Sinusoidal(non-operating)

The vibration spectrum is:

5Hz to 9Hz: 12mm peak

9Hz to 27Hz: 4g peak

27Hz to 200Hz: 5g peak

200Hz to 300Hz: 4g peak

300Hz to 2000Hz: 2g peak

Rate: 1 octave/min.

b) Random(non-operating)

The random profile is:

5Hz to 28Hz: linear from $0.0036g^2$/Hz to$0.08g^2$/Hz

28Hz to 250Hz: constant at $0.08g^2$/Hz

250Hz to 2000Hz: linear from $0.08g^2$/Hz to $0.0012g^2$/Hz

Duration: 1hours/ axis

3.7.7 Shock

The cooler shall not be damaged after exposure to shocks with the following levels:

a) Basic shocks(non-operating)

Waveform: 1/2 sine pulse

Acceleration, Duration: 25g, 6ms

Direction: the (+) and (-) direction of 3 axis

Number: 3 shocks per axis per direction (18 shocks total)

b) High Intensity shocks (non-operating)

Waveform: 1/2 sine pulse

Acceleration, Duration: 50g, 6ms

Direction: the (+) and (-) direction of 3 axis

Number: 3 shocks per axis per direction (18 shocks total)

3.8 Electromagnetic Radiation

The cooler (when properly connected for operation) shall comply with the following requirements.

CE102 – Conducted emission, power leads, 10 kHz～ 10MHz
CS101 – Conducted susceptibility, power leads, 25Hz ～ 50kHz
CS114 – Conducted susceptibility, bulk cable injection, 10kHz ～ 400MHz
RE102 – Radiated emission, Electric field, 10 kHz ～18 GHz
RS103 – Radiated susceptibility, Electric field, 10 kHz ～40 GHz

3.9 Reliability

The cooler shall have a Mean-time-To-Failure (MTTF) of at least 4,000 hours.

4 VERIFICATION

4.1 Classification of inspections

Inspections shall be classified as follows:

a) First article inspection (see 4.3)
b) Conformance inspection (see 4.4).

4.2 Inspection conditions

Except as otherwise specified herein, all examinations and tests shall be performed at the conditions of 3.1～3.4, GJB 150.1-1986.

4.3 First article inspections

First article inspections shall be performed by the contractor after award of contract and prior to production. First article inspection shall be performed on sample units which have been produced with equipment and procedures normally used in production.

4.3.1 Inspection requirement

Inspection requirements for First article are listed in Table 2.

4.3.2 Test

Three coolers are needed for First article inspections. 2 first article coolers shall be subjected to reliability testing and 1 first article coolers shall be subjected to all other tests listed in Table2. Tests may be conducted in any order.

4.3.3 Failure

If one or more sample coolers fail to meet any of the first article requirements and tests, the contractor shall immediately notify the government of the failure, the contractor shall determine the root cause of the failure and take appropriate corrective action. The contractor is required to submit a new set of first article samples which have incorporated the charges for inspection. A description of the failures and corrective action taken should be included in the first article inspection reports.

4.3.4 Disposition of first article samples

First article samples shall not be considered as part of the procurement quantities.

4.4 Conformance inspection

4.4.1 Classification of Conformance Inspection

Conformance inspection shall be classified as Group A, B, C.

4.4.2 Group A inspection

Group A inspection shall be conducted on all coolers. Group A tests listed in Table2 may be performed in any order unless otherwise specified. Failure of any test shall be cause for rejection of that unit.

Table2 Inspection requirements

S	Inspection	First article inspection	Conformance inspection			Requirement paragraph	Test paragraph
			A	B	C		
1	Size	●	●	–	–	3.1	Measure
2	Weight	●	●	–	–	3.3	
3	Electrical Connectors	●	●	–	–	3.2	Visual inspection
4	Workmanship	●	●	–	–	3.4	
5	Labeling and marking	●	●	–	–	3.5	
6	Refrigeration Controlling and Indication Functions	●	●	–	–	3.6.1	4.5.1
7	Accuracy and Stability of Refrigeration Controlling and Indication Functions	●	●	–	–	3.6.2	4.5.2
8	Cool-down time	●	●	–	–	3.6.3	4.5.2
9	Cooling capacity	●	●	–	–	3.6.4	4.5.2
10	Power consumption	●	●	–	–	3.6.5	4.5.2
11	Leak rate	●	●	–	–	3.6.6	4.5.3
12	Acoustic noise	●	–	–	●	3.6.7	4.5.4
13	Vibration output	●	–	–	●	3.6.8	4.5.5
14	High temperature, operating	●	–	●	–	3.7.1	4.5.6.1
15	High temperature, storage	●	–	–	●	3.7.2	4.5.6.2
16	Low temperature, operating	●	–	●	–	3.7.3	4.5.6.3
17	Low temperature, storage	●	–	–	●	3.7.4	4.5.6.4
18	Temperature shock	●	–	–	●	3.7.5	4.5.6.5
19	Vibration	●	–	●	–	3.7.6	4.5.6.6
20	Shock	●	–	●	–	3.7.7	4.5.6.7
21	Electromagnetic Radiation	●	–	–	–	3.8	4.5.7
22	Reliability	●	–	–	–	3.9	4.5.8
Note: ●:Need inspection, –: Needn't inspection							

Table 3 Group B Sampling plan

Monthly Lot Size	Number of sample units monthly
1-99	1
100-299	3
300-499	5
500-999	7
1000 or more	10

4.4.3 Group B inspection

Group B inspections shall be conducted on coolers selected from units which have passed the tests in 4.4.2 (see 6.2). The sample(s) shall be tested in accordance with the inspections listed in Table2.

4.4.3.1 Sampling for group B inspection

Samples shall be selected in accordance with Group B sampling plan listed in Table3 may be performed in any order.

4.4.3.2 Group B failures

Actions required relative to group B failures shall be as specified in the contract.

4.4.3.3 Disposition of group B samples

Group B samples shall be accepted on contract subsequent to the tests of Table2.

4.4.4 Group C inspection

Group C inspection shall be conducted on coolers selected from units which have passed the tests in 4.4.2. Group C sampling plan shall be specified in the contract. Group C inspection shall be in accordance with Table2.

4.5 Test methods

4.5.1 Refrigeration Controlling and Indication Functions

4.5.1.1 Test Equipment

a) Simulation Test dewar: The test dewar shall enclose the cold-finger and cold-station.
The cold-station shall be as a 250J±20J copper thermal mass (from 300K to 80K). The heat load of the test dewar at 23℃±2℃ should be in the range of 190mW to 220mW.
b) High vacuum system: The vacuum is at least $3*10^{-2}$ Pa.
c) The electric test system and the control's control box.

4.5.1.2 Mount Method

a) The test dewar shall be mounted on the cooler.
b) The cooler shall be filled with high purity Helium at a pressure according to the mark of the cooler.

c) The cooler shall be connected with the high vacuum system and with the electrical control box.

4.5.1.3 Test Method

a) Connect the electric connector to the cooler. The connector includes sockets of power lines and other electric wires. Connect the power lines to a regulated power supply. Connect the other electric wires (cool down, shut down, stand by and temperature diode leads) to the control box, and connect a voltmeter to the control box. There are switchers of SHUT DOWN, STBY, OPEN/CLOSE and light of COOL DOWN on the control box.

b) Turn the remote SHUT DOWN switch to OFF, the STBY switch to OFF, and run the cooler in close cycle operation.

c) Record the temperature diode voltage required to light the COOL DOWN lamp. After the cold temperature up to 1.048V, Verify the cold temperature stabilizes at 1.048±0.002V.

d) Operate the STBY switch and verify the cold temperature stabilizes at 1.029V±0.010V. Then return the STAND-BY switch to its initial position (OFF).

e) Operate the SHUT DOWN switch and see that the cooler motor has stop working and that the temperature reading continues.
Let the cooler warm up until the COOL DOWN lamp shuts down. Record the temperature reading when the indicator shut down.
Return the SHUT DOWN switch to its initial state (OFF).

f) Vary the power supply voltage between 18-28VDC. The change of the temperature voltage shall be not more than ±3K (±0.0054V).

g) At 10:00 minutes, Turn the OPEN/CLOSE CYCLE switch to open mode and measure the cooling capacity.

h) At 20:00 minutes, Turn the OPEN/CLOSE CYCLE switch to close mode, and remove the additional heat load on the cold tip.

i) After the cold temperature stabilizes, Observe the cold temperature stability to be within ±2K(±0.0034V) at 30:00 minutes.

j) Disconnect the cooler and the vacuum system. Use a digital multi-meter, connect one clip to one of sockets of the connector, and another (with an alligator clip) to the body of the cooler. Read the resistance to be not less than 20MΩ.

k) Use a digital multi-meter, connect one clip on one point of the body, and the other clip on another point of the body. Read the resistance to be not more than 0.2Ω.

4.5.2 Accuracy and Stability, Cool-down time, Cooling capacity, Input power

4.5.2.1 Test equipment: see 4.5.1.1.

4.5.2.2 Mount method: see 4.5.1.2.

4.5.2.3 Test Method

a) Connect the cooler to the stand in the climate chamber. Set the chamber temperature to the required temperature, stabilize for 60 minutes.
b) Start the cooler.
c) Measure and record the cooling time to the required cold tip temperature, and the maximum input power.
d) Let the cooler run at the CLOSE modes, record the fluctuations of the cold tip temperature at any constant ambient temperature in the range of -40℃～+70℃. (shall be less than ±2K(±0.0034V))
e) Record the deviation of the values at any ambient temperature in the range of -40℃～+70℃, from the values at ambient temperature 23℃±2℃. (shall be less than ±3K(±0.0051V))
f) Apply a head load to the cooler, record the cold tip temperature after 10 minutes. (the fluctuations of the cold tip temperature shall be less than ±2K) The total heat load equivalent to sum of the added heat load and the self heat load of test dewar.

4.5.3 Leak rate

Place the cooler under a test bell jar connected to a helium mass spectrometer, turn on the leak detection and read the leak rate.

4.5.4 Acoustic noise

The cooler shall be set up for operation in an area where the background noise level is at least 5 dB below the sound level to be measured. The cooler shall be operated and sound pressure measurements made with the cooler oriented in 4 positions in the same plane with each position approximately 90 degrees apart. Measurements shall be made with an octave-band analyzer.

4.5.5 Vibration output

The cooler shall be turned on for 15 minutes to allow it to reach equilibrium temperature. The acceleration shall be obtained by attaching an accelerometer to the area of cooler surface.

4.5.6 Environmental tests

4.5.6.1 High Temperature, operating

Temperature: +70°C ± 2°C
Duration: 30 minutes
Test content: Test the cooler as 4.5.2.

4.5.6.2 High Temperature, storage

Temperature: +85°C ± 2°C
Duration: 48 hours
Test content: Test the cooler as 4.5.2 after 2 hours from ending storage.

4.5.6.3 Low Temperature, operating

Temperature: -40°C ± 2°C
Duration: 30 minutes
Test content: Test the cooler as 4.5.2.

4.5.6.4 Low Temperature, storage

Temperature: -55°C ± 2°C
Duration: 24 hours
Test content: Test the cooler as 4.5.2 after 2 hours from ending storage.

4.5.6.5 Temperature shock

Low Temperature: -55°C ± 2°C
High Temperature: +85°C ± 2°C
Duration: 1 hour
Alternation: No more than 5 minutes
Number of cycles: 5
Test content: Test the cooler as 4.5.2 after 2 hours from ending shock.

4.5.6.6 Vibration

a) Sinusoidal(non-operating)

5Hz to 9Hz: 12mm peak
9Hz to 27Hz: 4g peak
27Hz to 200Hz: 5g peak
200Hz to 300Hz: 4g peak
300Hz to 2000Hz: 2g peak
Rate: 1 octave/min.

b) Random(non-operating):

The random profile is:
5Hz to 28Hz: linear from 0.0036g^2/Hz to0.08g^2/Hz
28Hz to 250Hz: constant at 0.08g^2/Hz
250Hz to 2000Hz: linear from 0.08g^2/Hz to 0.0012g^2/Hz
Duration: 1hours/ axis

Test the cooler as 4.5.2 after 2 hours from ending vibration.

4.5.6.7 Shock

The cooler shall not be damaged after exposure to shocks with the following levels:

a) Basic shocks(non-operating)

Waveform: 1/2 sine pulse
Acceleration, Duration: 25g, 6ms
Direction: the (+) and (-) direction of 3 axis
Number: 3 shocks per axis per direction (18 shocks total)

b) High Intensity shocks (non-operating)

Waveform: 1/2 sine pulse

Acceleration, Duration: 50g, 6ms
Direction: the (+) and (-) direction of 3 axis
Number: 3 shocks per axis per direction (18 shocks total)

4.5.7 Electromagnetic Radiation

The cooler shall be capable of meeting the requirements of 3.8 and shall be tested according to GJB152A-1997.

4.5.8 Reliability

A contractor prepared reliability test plan shall be used to demonstrate the reliability requirement of 3.9 and shall be tested according to GJB899-1990.

5 PREPARATION FOR DELIVERY

5.1 General

The cooler shall be preserved and packaged and packaged for electrical, mechanical, and physical protection in accordance with the requirements specified herein. The equipment shall be adequately cushioned, blocked, and braced, using suitable materials and containers as required, in such a manner as to afford maximum protection against corrosion, deterioration, and physical damage during storage and shipment.

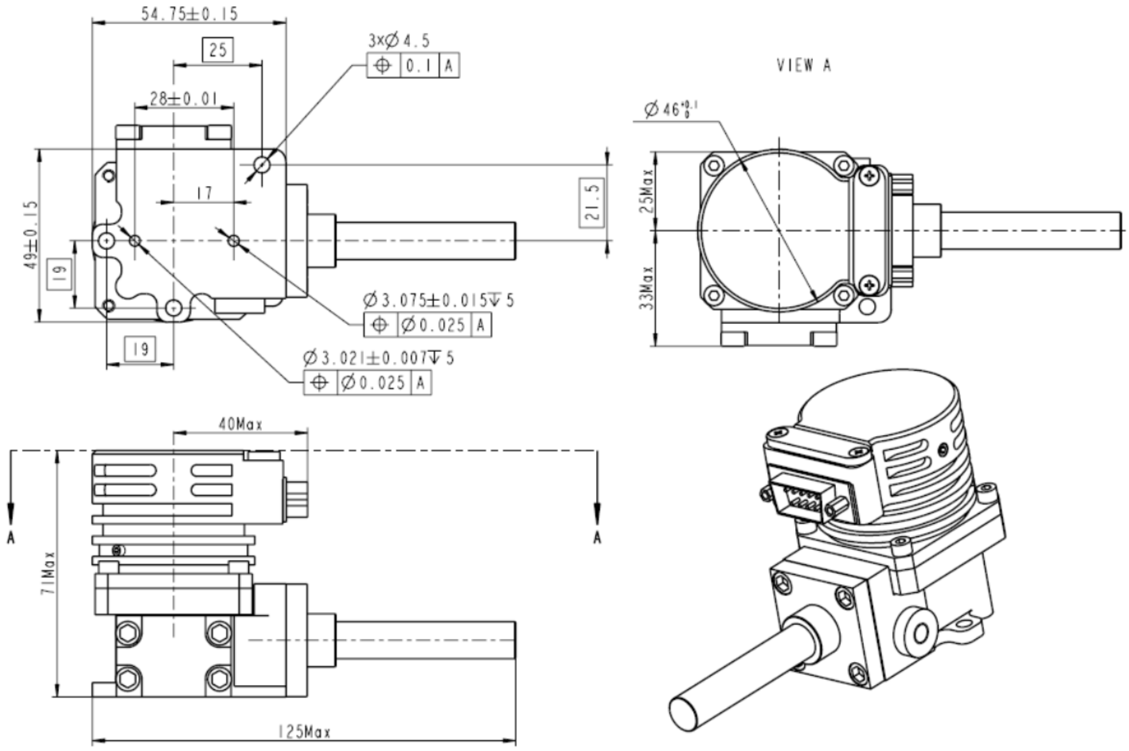
5.2 Packing

Packing shall be in a manner that will ensure acceptance by common carrier and safe delivery at destination. Shipping containers shall comply with the Uniform Freight Classification Rules, or regulations of other carriers, as applicable to the mode of transportation.

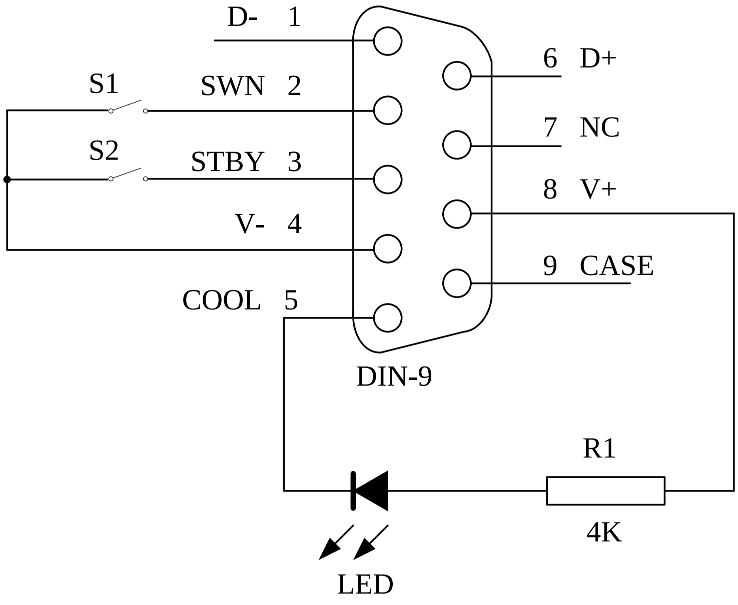
5.3 Marking

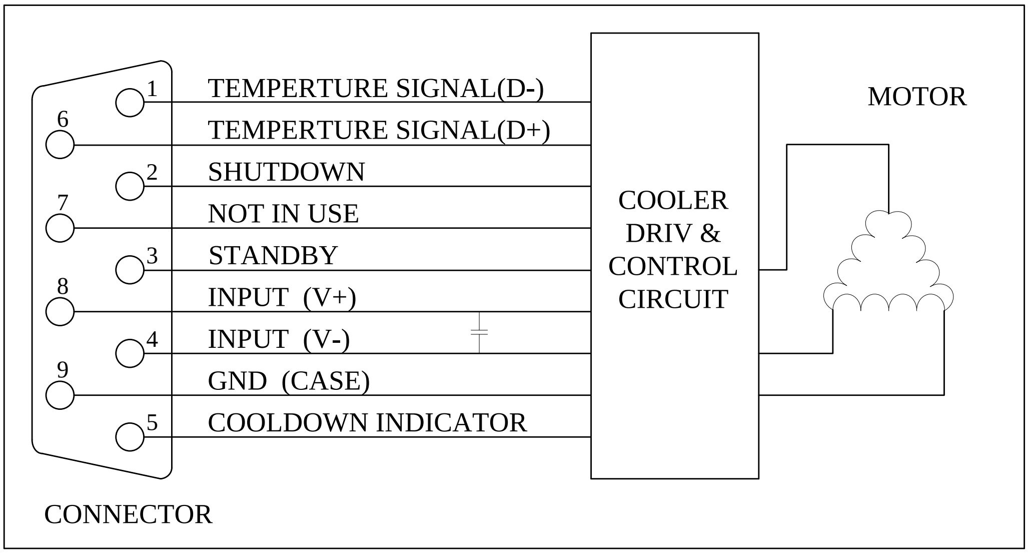
In addition to any special marking required by the contract or order, unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with TBD.

ANNEX 1 The outline configuration of the cooler SCI04R



ANNEX 2 The Electrical Connectors of the cooler SCI04R





INSTRUTION SHEET

FOR Cryogenic Cooler Model C04S With B49 Temperature Controller

General

This instruction sheet assumes that the cooler's operator has the basic skills in the cryogenic filed and the electrical instrumentation.

WARNING!

The cryogenic cooler is a delicate electromechanical instrument. Take special care when moving, assembling or operating to avoid electrical or mechanical damage.

1. The cooler is designed to operate from a direct voltage source in the range of （18-28） VDC.
2. The cooler can operate in two modes, but Close loop mode is recommended.

2.1 Open loop

In this mode the temperature control function will not be used, and the cooler will operate at full cooling capacity.

2.2 Close loop

In this mode the temperature control function will be used, and the cooler will stabilize on the pre adjusted cooling temperature which has been set previously by K.I.P. according to the costumer's definition.

3. Typical current in 24 VDC will be 0.3-0.55 Amp. (Open loop).
The current is affected by the ambient temperature and the motor temperature. Current limitation for continuous operation is 0.7 Amp.
Low current and weak cooling may be a result of loss of gas caused by an external leak.

Keep cooling shin temperature less than 80℃ by a proper heat removal or forced ventilation by blower. Cooler performances will be improved by lowering its skin temp.

4. The cold spot is produced only at the expander tip. Efficient heat transfer from the cold area to the detector is conditioned on the thermal coupling.
Special attention should be taken during the expander– Dewar integration to minimize the problems.
5. The cooler is manufactured from anticorrosion materials, but a continuous contact with corrosive solution or materials may cause local corrosion, avoid direct contact or cooler exposure to corrosive environment.

Opening or disassembling of the cooler is strictly forbidden without K.I.P.'s written permission! Such an action will void K.I.P.'s warranty!

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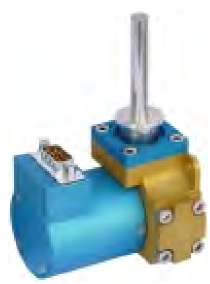
- Joule Thomson Mini Coolers
- Stirling Cryocoolers
  - Integral Stirling Cryocooler System with rotary drive
  - Split Stirling Cryocooler System with rotary drive
- Pure Air Monitors

INTEGRAL STIRLING CRYOCOOLER – ROTARY DRIVE

Description:
The cooler is intended for use in IR applications but can be used also in other applications. Le-tehnika's New Integral rotary Stirling cryocooler model SRI401 was developed on a basis of good results of the previous family ISMO with an aim of a longer life time and a smaller power consumption.
The concept of the direct integration of a detector on a cooler cold finger (DDCA) was implemented by the Expander design.

Picture:



Advantages:
- The operation of the Stirling compressor driven via DC brushless motor is smooth and silent, with low vibrations and an acoustic noise.
- Motor windings are outside of the working gas to prevent its contamination and prolong the lifetime and reliability of the cooler.
- Digital electronic drive is integrated in the cooler.

Technical Datasheet:
Brochure

For all other informations please do not hesitate and contact us on e-mail: cryogenics@le-tehnika.si or telephone number: +386 4 20 20 280.

Experts in Cryocooling

INTEGRAL STIRLING COOLER – SRI401
(0,5W@80K)

The cooler is intended for use in IR applications but can be used also in other applications.

Le-tehnika's New Integral rotary Stirling cryocooler model SRI401 was developed on a basis of good results of the previous family ISMO with an aim of a longer life time and a smaller power consumption.
This model is a member of a new more reliable family of rotary driven Stirling coolers with main improvements on compressor side and also on expander.
The concept of the direct integration of a detector on a cooler cold finger (DDCA) was implemented by the Expander design.
The operation of the Stirling compressor driven via DC brushless motor is smooth and silent, with low vibrations and acoustic noise. Motor windings are outside of the working gas to prevent its contamination and prolong the lifetime and reliability of the cooler.
Small digital electronic driver with an onboard temperature controller is also fully programmable via RS232 port for a custom mission profile. Over-current protection, standby mode and remote shutdown are available as an option. The electronic board is integrated into the end of the electromotor. Different motor connections possible.

PERFORMANCE SPECIFICATIONS:
(for an ambient temperature of 23 °C)

Input Voltage: …………………………………	21-28 VDC
Typ. Steady State Input Power: ……………..	(200mW @80K @ 23°C): 8W Typ.
Cooldown time to 80K (200J): ………………..	< 5 min
Maximum Input Power Required: ……………..	17 W (during cooldown)
Operating Ambient Temperature Range: …….	- 40 °C to + 71 °C
Weight: …………………………………………	< 470gr
MTBF: ……………………………………………...	> 10000h (Expected)

Meets Environmental Conditions per MIL-STD-810D

Optional cold finger designs are possible upon request.

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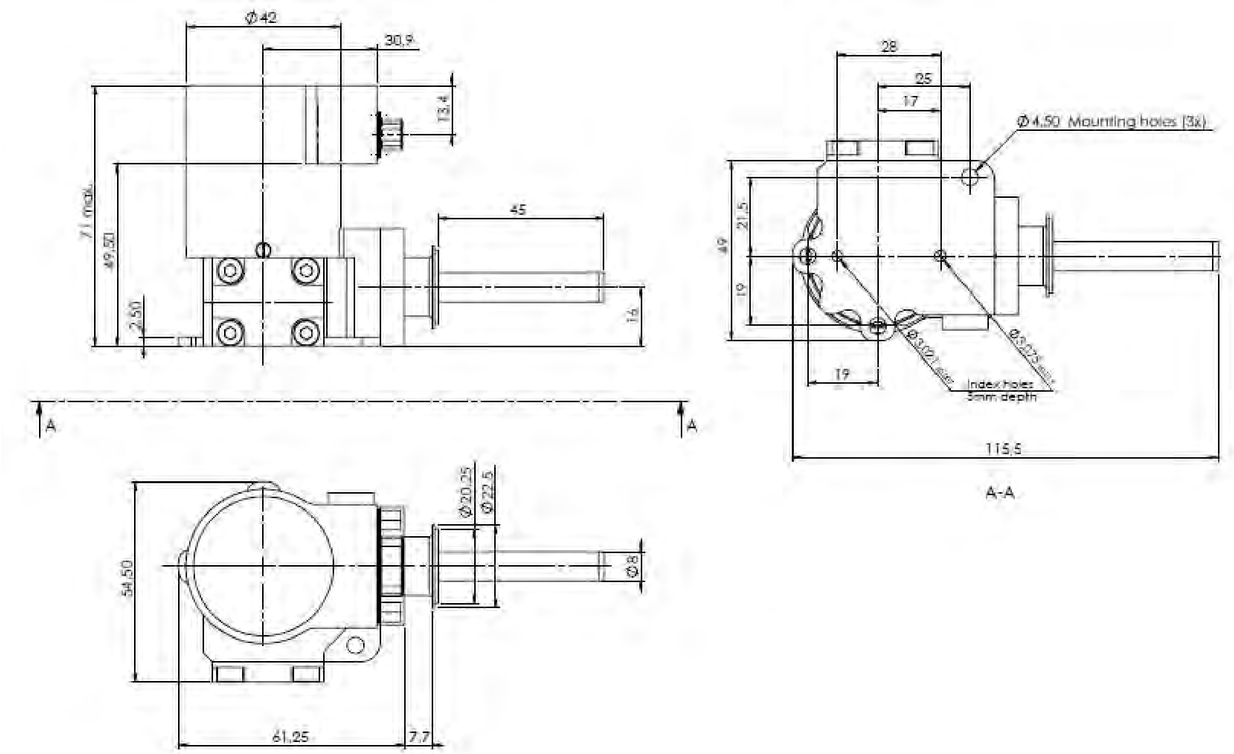
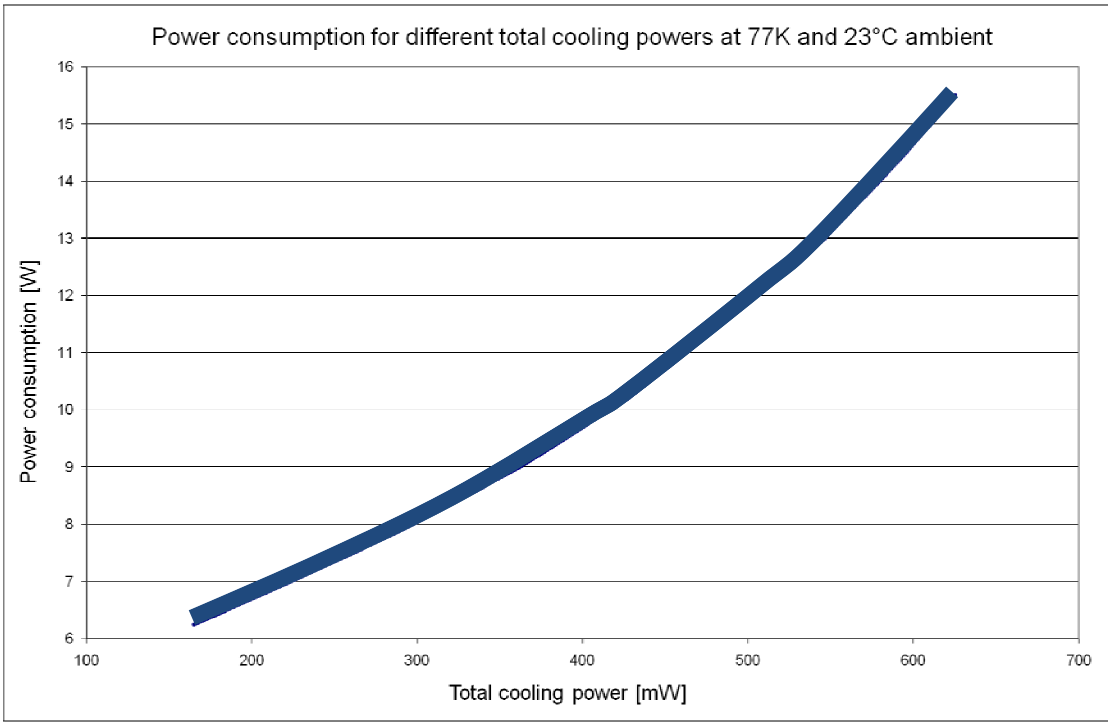
cryogenics@le-tehnika.si
http://www.le-tehnika.com/cryogenics/program.htm

Experts in Cryocooling

Dimensions:



Electrical power consumption for different total cooling powers at 77K and 23°C ambient:



Specifications are subject to change without notice

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Gas Infrared Camera for SF6 Finder MTG 80

Sulfur Hexafluoride, SF6 is an insulation gas used widely in high voltage equipment, the aging of equipments can cause SF6 leakage and emissions, and SF6 is greenhouse gas with a global warming potential of 23,900 times the potential of CO2. Gasfinder MTG infrared camera can detect accurately leakage spot from faraway distance to prevent hazards workers and public, also preserve the environment now and for future generations.

SF6 gas has significant impact of global climate change, also has strong capacity of infrared absorbance. MTG80 is particular gas camera to detect SF6 leaks and offer bright and vivid thermal images to verify the leaks location rapidly and accurately. It is ideal instrument to be used widely in gas-insulated substations, circuit breakers, and other switchgear.

Product Features

High sensitivity: with advanced technology to make it is capable to detect SF6 leaks with 194g gas leakage rate per year
Auto operation: instrument can be adjusted automatically laser intensity, make measurement easily and accurately.
Dual display design: crisp seeking imaging + LCD screen, can operate in the sunlight.
Built-in 4.0 mega-pixel digital camera: provide bright and vivid images.
Inspection safety: detect potentially dangerous leaks to be monitored from several meters away.

Application

MTG GasSee Infrared Camera is specialized for high voltage and ultra-high voltage power industry using SF6 gas as insulation. MTG GasSee product can detect SF6 gas leakage efficiently and accurately in a safe distance.

(/request/brochure-request.html)

Request for product brochure (/brochure-request)

FTIR Gas Analysis

WWW.MKSINST.COM

Technology for Productivity

AIRGARD® CWA/TIC

AMBIENT AIR ANALYZER FOR CONTINUOUS CHEMICAL WARFARE AGENT (CWA) AND TOXIC INDUSTRIAL CHEMICAL (TIC) MONITORING

RAPID RESPONSE • VERY LOW FALSE ALARMS • HIGH RELIABILITY • SELF CONTAINED

The MKS AIRGARD ambient air analyzer is an ultra-sensitive, Fourier Transform Infrared Spectroscopy (FTIR) based gas analyzer designed to rapidly detect toxic gases. The analyzer is capable of detecting parts per billion (ppb) levels of most CWAs and TICs below toxic, Immediately Dangerous to Life or Health (IDLH) levels within 20 seconds. This low level detection and fast response ensure sufficient time for an appropriate response such as: shutting down air handling systems, 'shelter in place' or evacuation of the affected area. The AIRGARD analyzer has been thoroughly tested by the Department of Defense for its sensitivity, specificity, response time, and immunity to false positive alarms caused by the sensing of, and alarming to, everyday benign, non-toxic solvents and industrial chemicals. This immunity to false alarms prevents unwarranted evacuation of buildings, associated interruptions of business, and emergency notifications when no threat materials are present in the building airflow.

Features & Benefits

- ppb detection limits – ability to discriminate and alarm to a broad range of threat substances. The AIRGARD analyzer has been tested against all ARFCAM listed threat gases, mixtures of threat agents and common interfering materials with no false positive alarms.
- Rapid response – typical time to alarm and identify threat agents < 20 seconds
- Automated, stand-alone operation – self-contained analyzer with embedded computer and sampling pump
- Continuous (24/7) air monitoring
- Ethernet connectivity and monitoring for remote troubleshooting
- Reliability – rugged design with minimum downtime
- Low maintenance – only occasional filter changes required
- High selectivity with ability to adapt to evolving threats – large "background" library file (375+ gases) with custom gas additions available
- Safety Act Designation

Applications

- Building air handling monitoring
- Enclosed public area air monitoring (arenas, subways, airport terminals, large office buildings, etc.)
- Air sampling and threat warning around CWA and TIC manufacturing and storage facilities — Chemical Facility Anti-Terrorist Standards (CFATS)

AIRGARD® Analyzer Operation

In the typical, non-alarming mode, the panel mounted "Gas Alarm" LED is green, indicating the sampled air is safe from toxic gases. If a toxic gas is detected within the concentration and probability limits set in the operational setup file, the "Gas Alarm" LED will change from green to flashing red. In addition to the visual, panel mounted status indication, the AIRGARD analyzer can communicate via Ethernet link to a sensor platform system to alert or alarm a command and control facility within the subject building. The AIRGARD analyzer will remain in this mode until a trained user acknowledges the alarm and initiates the necessary safety actions. In addition, if any of the sensor parameters (flow, temperature and pressure) are determined to be out of their optimal range, the "System Alarm" LED will turn yellow or possibly red (depending on the severity of the fault) and will communicate this information remotely via the Ethernet TCP/IP interface using an XML-based remote monitoring and control protocol. This interface uses state-of-the-art encryption technology to ensure a secure and robust connection between the remote AIRGARD analyzer and a central receiving computer.

The AIRGARD air analyzer is a totally self-contained monitoring device, having a sampling pump, FTIR spectrometer, controlling electronics and computer enclosed in a package measuring 18.5" x 24" x 7.5" which can be easily wall mounted. All AIRGARD air analyzers are individually tested for optimum signal-to-noise which ensures that consistent, reliable air monitoring will be provided in multiple deployments. The AIRGARD analyzer self calibrates after installation, constantly self checking the system health. This ensures readiness should a specified and applicable threat substance be introduced into the sampled air flow.

Specifications

Packaging

Dimensions	18.4" (W) x 25.4" (H) x 7.5" (L) [46.7 x 64.5 x 19.1 (cm)]
Weight	75 lbs. [34.1 kg]
Installation	Wall mount (bracket included)
Power Requirements	120 VAC, 50/60 Hz, 3A, 240 VAC available
Operating Temperature	10 to 40°C
Operating Humidity	Up to 65%

User Interface

Communication	TCP/IP (Ethernet); 1 USB port; XML Standard Protocol

Compliance Testing

The AIRGARD analyzer has been designed and tested to be fully compliant with the following:

- European Electromagnetic Compatibility Directive 89/336/EEC — assures product tolerance to:
  - – Electrical stresses such as ESD (Electro Static Discharge)
  - – EMF (Electro Magnetic Fields)
  - – Transients
  - – Surges
  - – RFI (Radio Frequency Interference)

NOTE: Substance Specific Reports Available Upon Request

Ordering Information

Please contact your MKS Sales office for price and availability information.

mks Technology for Productivity

Global Headquarters

2 Tech Drive, Suite 201
Andover, MA 01810

Tel: 978.645.5500
Tel: 800.227.8766 (in USA)
Web: www.mksinst.com

MKS, FTIR/NDIR Analysis

651 Lowell Street
Methuen, MA 01844

Tel: 978.645.5500

THALES Cryogenics

W / 8 mm IDCA

RM3
550 mW / 8 mm IDCA

Category: RM Rotary monobloc coolers. Tags: IDCA, Rotary.

Description

Product Description

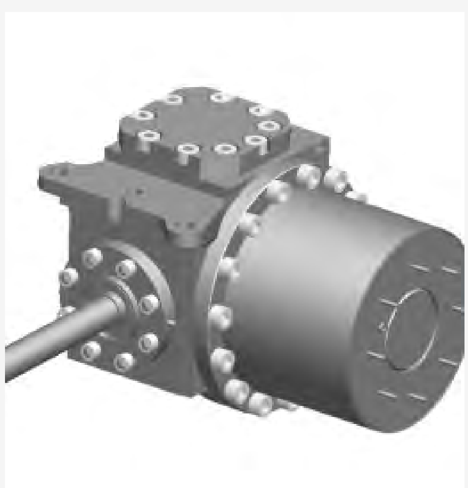
The RM3 is a high-performance rotary cooler for 8 mm IDCA dewars. As the drive electronics are integrated, no separate controller board is necessary for the RM3.

Properties

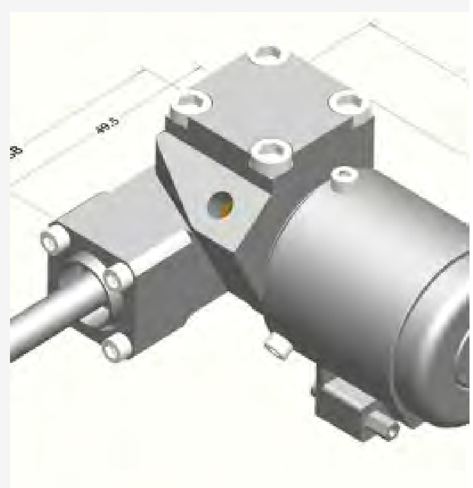
- Cold finger / approx. dewar bore: 8 mm IDCA
- Mass: 450 g
- Cooling power @ 110K/20°C: >550 mW
- Steady state input power: < 5.3 W
- Cooldown time to 77K @ 150J: < 6 min.
- Low noise: < 45 dBA

Related Products

RM2



RM4



RM1

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Directorate of Defense Trade Controls
DDTCPublicComments@state.gov
Washington, DC

RESPONSE TO REQUEST FOR COMMENTS RE: USML CATEGORY XII

On May 5, 2015, the Department of State, Directorate of Defense Controls (DDTC) issued a Federal Register Notice soliciting comments from industry on the implementation of Export Control Reform (ECR) with respect to fire control, range finder, optical and guidance and control equipment and setting the deadline for such comments as July 6, 2015. Riegl USA, Inc. ("Riegl") respectfully submits the following comments. Thank you for your consideration.

EXECUTVE SUMMARY
We appreciate the USG's efforts to more accurately describe the articles in this category in order to establish a "bright line" between the USML and the CCL for the control of these articles. However, the proposed rules place new controls on certain existing Riegl commercial products that will negate many of the intended benefits of ECR with respect to the items in this category, including Laser rangefinders and Light detection and ranging ("LiDAR") systems.

Because we are one of the few LiDAR manufacturers in the world that manufactures commercial LIDAR's and operates in the United States, we are concerned that the proposed changes to USML Category XII could uniquely disadvantage our firm when competing for commercial applications against Global competitors.

Such proposed revisions to Category XII(b) would result in the transfer of many commercial products to the USML that were previously not USML controlled. These products were designed, and are predominately used, for commercial applications. They were not designed for military use.

The fact that existing commercial Laser rangefinders and LiDAR products may possess parameters or characteristics that provide a critical military advantage means that the proposed control of these commercial products would cross the "bright line" from the CCL to the USML. As such, we believe that it would be in the best interest of the Government and industry to clearly specify that such items are controlled in the USML only if they are

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specially designed for military use. Riegl develops and manufactures commercial LiDAR survey instruments for airborne, mobile and terrestrial mapping applications, as do many other companies.

Detailed comments are provided below. The specific categories for which we are providing comments are:
Paragraphs (b)(3), (b)(4), (b)(6) and (b)(8)(ii,v,vi)

Comments to Category (b) – Lasers, and laser systems and equipment

1. (3) Laser rangefinders having any of the following:
(i) Q-switched laser pulse; or
(ii) Laser output wavelength exceeding 1,000 nm;

Comment: We are concerned that this wording, as proposed, would capture many Laser rangefinders that were developed, and are currently used, for commercial applications. These products, which were not specially designed for military applications, or to military specifications, may employ a Q-switched laser pulse and operate at a laser output wavelength exceeding 1,000 nm.

We understand that the particular laser rangefinders that are of interest to the government would be used primarily for locating military targets. These military rangefinders are typically designed for long range (several kilometers), with an accuracy between one and five meters. Commercial rangefinders, on the other hand, are required to have much better accuracy (e.g. 5 cm) and lower range capability (normally less than one kilometer).

To prevent the inadvertent control of Laser rangefinders on the ITAR that are in normal commercial use, we suggest the following wording for paragraph (b)(3):

"(3) Laser rangefinders specifically designed for military use, and having any of the following:
(i) Q-switched laser pulse; or
(ii) Laser output wavelength exceeding 1,000 nm;"

2. (4) Targeting or target location systems or equipment incorporating or specially designed to incorporate a laser rangefinder controlled in paragraph (b)(3) of this category, and incorporating or specially designed to incorporate a Global Navigation Satellite System (GNSS), guidance or navigation article controlled in paragraph (d) of this category (MT if designed or modified for

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rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km range);
Comment*:* If the suggested changes are made to paragraph (b)(3), then we suggest no changes to this language.

3. (6) Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);
Comment: Commercial products, in some cases, incorporate an ITAR-controlled IMU (an article controlled in this subchapter), which is required for accurate topographic mapping. In other cases, a non ITAR-controlled IMU is incorporated into the same product. We suggest removing the wording "*or specially designed to incorporate*", so that the product is controlled only if it physically incorporates an article controlled in this subchapter.
Such commercial products were not designed for military use, so it would seem unwise to have such items ITAR controlled if they do not incorporate an ITAR item. Several Riegl products fall into this category. We are concerned that having these commercial products become subject to the USML would severely limit sales potential and control products that have been sold commercially without a BIS license for many years.

4. (8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):
(ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);
Comment: Many commercial LiDAR systems, operating at wavelengths exceeding 1,000 nm, currently have the capability to detect power lines having a diameter of 10 mm, from a distance of 500 m. Such products were designed for commercial topographic mapping and not specially designed for military use. Due to their inherent design, these systems are capable of carrying out power line mapping for commercial applications, and have been doing so for over 15 years. For example, Riegl's commercial LMS Q680i, LMS Q780, LMS Q1560, VUX series and other airborne laser terrain mappers are able to detect power lines to within 5 mm from an altitude of 600 m. In this case, our

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commercial systems have already demonstrated a capability that exceeds the proposed ITAR limits.

To avoid controlling such items on the ITAR, that are in normal commercial use, we suggest the following wording to paragraph (b)(8)(ii):
"***(ii) Aircraft systems or equipment specially designed for military use and having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);"***

5. (8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):
(v) Systems or equipment that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs);
Comment: Some commercial airborne LiDAR bathymetric systems, designed for measuring water depth and mapping water-bottom topography, could be used for automatic identification of submersibles, due to their inherent design. Riegl has several products in this category, including our VQ 820G and VQ 880G systems. These products were not designed for military applications. As with the previous comments, to avoid inadvertent control of such items on the ITAR, we recommend the following wording for paragraph (b)(8)(v):
"(v) Systems or equipment specially designed for military use and that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs);"

6. (8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):
(vi) Systems or equipment specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;
Comment: Similar to category *(8)(v)*, some commercial ground-based laser imaging and mobile mapping products, not specially designed for military use (e.g. for obstacle avoidance), can be useful for obstacle avoidance applications, due to their inherent design, either as is, or with minor modifications. Riegl has already sold the VQ380 commercial product used by the USN in the AACUS autonomous system. There are other commercial products –VQ, VZ series, VMX series and VMQ series – could be used for obstacle avoidance applications.

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As with the previous comments, we suggest the following wording for paragraph (b)(8)(vi):
" ***(vi) Systems or equipment specially designed for military use and specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;"***

Inputs on Requested Items

1. Items proposed for control on the USML or the CCL that are not controlled on the Wassenaar Arrangement's Munitions List or Dual Use List.

Comment: LiDAR systems are presently not controlled on the Wassenaar Arrangement's Munitions or Dual Use List, whereas LiDAR systems are proposed for control in USML Category XII(b) (6),(7) and (8).
LiDAR systems were previously not controlled on the USML, unless they specifically incorporated an ITAR-controlled item. LiDAR systems are not controlled on the CCL, except for ECCN 6A008.j, which was introduced a few years ago:
j. Being "laser" radar or Light Detection and Ranging (LIDAR) equipment and having any of the following:
j.1. "Space-qualified";
j.2. Employing coherent heterodyne or homodyne detection techniques and having an angular resolution of less (better) than 20 µrad (microradians); *or*
j.3. Designed for carrying out airborne bathymetric littoral surveys to International Hydrographic Organization (IHO) Order 1a Standard (5th Edition February 2008) for Hydrographic Surveys or better, and using one or more lasers with a wavelength exceeding 400 nm but not exceeding 600 nm;
Note 1: *LIDAR equipment specially designed for surveying is only specified by 6A008.j.3*.
As indicated in the note to 6A008.j, LiDAR equipment specially designed for surveying is only specified by 6A008.j.3.

2. Although the proposed revisions to the USML do not preclude the possibility that items in normal commercial use would or should be ITAR-controlled because, e.g., they provide the United States with a critical military or intelligence advantage, the U.S. government does not want to inadvertently control items on the ITAR that are in normal commercial use. Items that would be controlled on the USML in this proposed rule have been identified as possessing parameters or characteristics that provide a critical military or intelligence advantage. The public is thus asked to provide specific examples of items, if any, that would be controlled by the revised USML Category XII that are now in normal commercial

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use. The examples should demonstrate actual commercial use, not just potential or theoretical use, with supporting documents, as well as foreign availability of such items.

Comment: As mentioned previously, Riegl develops and manufactures LiDAR and camera survey instruments for airborne, mobile, unmanned and terrestrial mapping applications, including the following products:
Airborne LiDAR Systems
VP-1 VQ-880-G LMS-Q1560 LMS-Q780 VQ-820-G LMS-Q680i VQ-580 VQ-480U VQ-380i LMS-Q240i VQ-480I

Mobile LiDAR Systems
VMQ-450 VMZ VMX-450 VMX-450-RAIL VQ-450 VQ-180

Unmanned LiDAR Scanners VUX-1 Series RIEGL RiCOPTER VUX-1UAV RiCOPTER VQ-480-U RiCOPTER with VUX_SYS

Terrestrial LiDAR
Systems VZ-2000 VZ-1000VZ-400 VZ-4000 VZ-6000

Industrial LiDAR
Systems PH 400/1000 VZ-400-S LMS-Z210ii-S LMS-Q20 LMS-Q120ii

These products were developed for, and are presently in, normal commercial use. Currently, they are not controlled by the USML and do not require a Commerce Department license to be exported as CCL items. However, under the new proposed rules, they would be subject to ITAR Controls.

All of the above products were originally designed to incorporate an ITAR-controlled IMU, due to its small size and high accuracy – performance characteristics necessary for commercial surveying and mapping applications. Recently, however, the design of these products has been modified to accept IMUs that are not ITAR controlled, for those applications where size and/or accuracy is not as critical. With the current proposed rules, these products may be caught by paragraph (b)(6).

These airborne LiDAR survey instruments that operate at wavelengths of 1064 nm and/or 1550 nm and incorporate lasers with high pulse-repetition-rate lasers (up to 500 kHz) and pulse energies up to 50 microJoules. These specifications, which are critical for commercial surveying and mapping applications, are also sufficient for detecting power lines. In fact, some of our products have been used for mapping power lines as long as 15 years ago. With the current proposed rules, these products would now be caught by paragraph (b)(8)(ii).

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VQ 820G and the VQ 88oG are airborne LiDAR survey instruments that were developed for commercial survey applications, including water depth measurement, mapping water-bottom topography, and water-column measurements. Due to their inherent design – incorporating high pulse rate visible lasers (532 nm) with sufficient pulse energy – they are able to detect submersibles in the water column. With the current proposed rules, these products would now be caught by paragraph (b)(8)(v).

Mobile and Terrestrial Systems are commercial ground-based LiDAR systems that were designed for 3-D imaging and mobile mapping. Due to their inherent design – incorporating high pulse-rate lasers with small beam divergence – they could be used for obstacle avoidance applications; e.g. detecting ground vehicles. With the current proposed rules, these products would now be caught by paragraph (b)(8)(vi).
Brochures for the above products are to be reviewed at www.rieglusa.com.

CONCLUSIONS

1. It is our understanding that the intent of U.S. ECR is that items that are in normal commercial use and not specially designed for military use would not become subject to the USML. At the same time, we recognize that such items may possess parameters, or characteristics, that provide a critical military or intelligence advantage. Doing so crosses the "bright line" between the USML and the CCL. We believe that the USML should not control such items unless they have been specially designed for military use. As such, we recommend additional wording that would only capture items that are specifically designed for military use.

2. The existing USML Category XII(b) only refers to "lasers specifically designed, modified or configured for military application…". This clearly excludes LiDAR systems that were designed, and are currently used, for commercial applications. The proposed revisions would have a negative impact on industry and the future exports of these products. International business would be negatively affected by having commercial items controlled in the USML, as many companies and agencies are reluctant to procure items that

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are ITAR controlled. Riegl has had such responses from potential customers.

We appreciate DDTC's consideration of these issues. Thank you

Sincerely,

James H Van Rens
CEO
Riegl USA, Inc.

From:	Robert Badzey
To:	DDTCPublicComments
Subject:	ITAR Amendment - Category XII
Date:	Monday, July 06, 2015 5:04:07 PM

Concerning the USML Category definition, can you clarify what is meant by paragraph (b)(8)(v)? Does the identification of the constituent components of the ordnance or IED, rather than the completed device, fall into this definition? For instance, the residue of explosive commonly used in these devices.

Regards,

--
Robert Badzey, Ph.D.
Product Scientist
Eos Photonics, Inc.
mobile: 617.285.5899
office: 617.945.2214
badzey@eosphotonics.com

Gary Cotton
Sr. Product Classification Specialist
Export and Import Compliance
Office of the General Counsel

Rockwell Collins

400 Collins Road NE
Cedar Rapids, IA 52498
319.295.7073 Fax 319.295.8909
gary.cotton@rockwellcollins.com

July 6, 2015

Mr. C Edward Peartree
Director, Office of Defense Trade Controls Policy
US Department of State

Re: Comments Related to Revision of U.S. Munitions List Category XII

Dear Mr. Peartree:

Rockwell Collins appreciates the opportunity to provide comments on the proposed Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII (RIN 1400–AD32), published in the Federal Registrar on May 5, 2015.

Rockwell Collins, Inc. is an industry-recognized leader in the design, production and support of communications and aviation electronics for commercial and military customers worldwide. While our products and systems are primarily focused on aviation applications, our Government Systems business also offers products and systems for ground and shipboard applications. The integrated system solutions and products we provide to our served markets are oriented around a set of core competencies: communications, navigation, automated flight control, displays/surveillance, simulation and training, integrated electronics and information management systems. We also provide a wide range of services and support to our customers through a worldwide network of service centers, including equipment repair and overhaul, service parts, field service engineering, training, technical information services and aftermarket used equipment sales. We are headquartered at 400 Collins RD NE, Cedar Rapids, Iowa 52498 and employ approximately 20,000 individuals worldwide.

Regarding the proposed changes to United States Munitions List (USML) Category XII – Fire Control, Range Finder, Optical and Guidance and Control Equipment; Rockwell Collins submits the following comments:

Rockwell Collins integrates longwave and shortwave infrared components into airborne vision systems exported and sold to commercial airframers worldwide. The served market includes US, Brazilian, European, Russian, Chinese and other countries' commercial aircraft manufacturers, whose customers in turn operate both airliners and business and regional aircraft with global reach.

Global revenues for such commercial vision systems, designed to enable flight operations in low visibility and smog, are expected to total billions of USD over the next decade, especially as a result of a recent Chinese Government mandate to equip all new civilian aircraft and a substantial portion of the existing commercial fleet with these systems and related technologies.

The market for commercial airborne vision systems is extremely competitive, and Rockwell Collins experiences formidable competition from European, Israeli and Canadian suppliers.
In recent competition with these suppliers at prime foreign OEMs, Rockwell Collins' products have been negatively impacted by US export regulations. The uncertainty caused by the unpredictability in obtaining an export license, pose a supply chain risk to our customers, who therefore judge our products as risky. When presented with alternative products from foreign suppliers, not subject to US export regulations, our customers are attracted by the lower risk posed to their supply chain. Further, Rockwell Collins' product designs and specifications are necessarily very conservative to ensure a positive exportability judgment. As a result, our competitors' specifications often exceed those of our systems, causing Rockwell Collins to be at a technical disadvantage.

Our competitors source their components from numerous foreign focal plane and camera core suppliers, not subject to US technology export controls. A 2012 report by the Bureau of Industry and Security ("Critical Technology Assessment: Night Vision Focal Plane Arrays, Sensors and Cameras") identified a number of foreign suppliers of fundamental detector and camera technologies highly competitive with those provided by US suppliers; the foreign sources of these technologies are unhampered by US export controls and can therefore innovate, produce and supply systems more efficiently than US manufacturers and integrators. While an analysis is beyond the scope of these comments, it is quite clear that some of the foreign suppliers have substantially improved their product lines since issuance of that report. The improvement is largely due to market demand for their high-end, uncontrolled, products from foreign integrators not bound by the Wassenaar rules, as a non-participating country, directly competing with Rockwell Collins.

In fact, if one were to compare the forecast product lines from foreign suppliers and US suppliers of infrared components, one might conclude that innovative, high-end components are being developed at a faster rate by foreign suppliers. These foreign suppliers know they will be able to sell their components unencumbered to foreign integrators.

A related technology is also of interest to Rockwell Collins, and also being considered for regulation under export reform, namely technologies related to Near-Eye Displays. Near-Eye displays are the natural means of displaying cockpit information on various airborne platforms and are especially being considered for deployment on commercial rotorwing platforms. Rockwell Collins is in various stages of development of Near-Eye Display systems (sometimes referred to as "Head-Worn" or "Helmet-Mounted" displays, depending on their implementation). Here again Rockwell Collins competes with foreign suppliers who are unencumbered by export controls, and leveraging this advantage with OEMs.

Today it is very difficult to determine the "bright line" between what is clearly exportable and what may be subject to restrictions. In practice, the only low risk path for this determination is a lengthy and somewhat opaque process of individual application through a Commodity Jurisdiction ruling request. In addition, the underlying technologies evolve rapidly, and it is difficult to plan around future product improvements due to the uncertainty in the export classification.

The newly proposed "bright line" remains ambiguous. That is, it appears no more clearly defined as a result of the proposed rules. Rockwell Collins suggests, from a product planning standpoint, in cases of commercial aviation products with multi-year planning, certification and production cycles, it would be advantageous to have exportability rules based on the availability of components in the global market. For example, Rockwell Collins would support a process where products available in the global marketplace could automatically drive the export classification of our systems. If we designed a system around a component with a given set of specifications, and a functionally similar component were available without export restrictions from a foreign supplier, it would follow automatically, without a specific CJ application, that the system should be exportable under EAR.

Sincerely,

Gary Cotton
Sr. Product Classification Specialist
Export & Import Compliance
Rockwell Collins, Inc.

From:	Asher, Sanford A
To:	DDTCPublicComments
Cc:	Shepard, Mike; exportcontrols@hq.dhs.gov
Subject:	ITAR Amendment - Category XI
Date:	Saturday, July 04, 2015 5:04:22 PM

Dear Sir or Madam,

I am writing you in response to your request that I review changes in export control regulations with repect to optical devices, and spectroscopic devices and methodologies used for standoff detection of hazardous chemical and biological threats. I am a Distinguished Professor of Chemistry at the University of Pittsburgh. My lab is an international leader in the development of standoff detection methods for explosives and development of new methods for detecting hazardous species. I am presently funded by ONR and DTRA and was previously funded by DHS.

I am very concerned that export control regulations of the optical components could make it impossible to continue academic frontier research in the US. The fear is that typically used lasers and optical components will be so controlled that they cannot be easily obtained in the US. This could occur even though these components are easily available throughout the world.

I examined the ITAR Category XII Guide and found the following Technological Subcategories listed: Infrared lenses, mirrors, beam splitters, combiners and filters. I typically use the optical components on a daily basis and my work requires overnight access to these components as the need arises. If these devices were restricted I would not be able to compete with foreign scientists.

I would also make the same arguments for the following list of Technological Subcategories: Low Power Lasers, High Power Lasers, Tunable Lasers, Low Light Cameras, Cameras in General, Image Intensifiers.

In fact the list I examined here contains all the components used in modern spectroscopy and optics research. Over regulation would hinder basic and applied research.

I would be pleased to discuss these issues with you in detail.

Regards,

Sanford Asher,
Dist. Professor of Chemistry

SCHOTT

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Via DDTCResponse Team@state.gov

July 3, 2015

U.S.Department of State
Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
2401 E Streets, N.W.
12th Floor, SA-1
Washington DC 20522

Attention: Mr. Ed Peartree, Director, Office of Defense Trade Controls Policy, U.S. Department of State.

Regarding: Request for comments to proposed changes to ITAR Category XII.

Dear Mr. Peartree,

SCHOTT North America Inc., is a glass material, part and component manufacturer who supplies the United States and international marketplace. Our Advanced Optics Group supplies optical material, parts and components, the SCHOTT Lighting and Imaging Business Unit produces fiber optic parts and components, and our Electronic Packaging Business Unit produces electronic packaging parts and components. All of them service the commercial and defense markets, depending upon customer requirements.

SCHOTT North America Inc., recognizes and appreciates the current initiative to revise the previous export rules and regulations.

We would like to take this opportunity to comment on the proposed changes to Category XII of the ITAR.

Specific Comments and Request regarding Category XII.

1. Export control reform of Category XII creates the new category 6A615. Of particular concern to SCHOTT, is the inclusion of "blanks" of certain types of material.

   6A615 Military fire control, range finder, and optical, equipment, and "specially designed" "parts," "components," "accessories," and "attachments," as follows (See List of Items Controlled).

   c. Zinc selenide, zinc sulfide, germanium or chalcogenide optics blanks, being flat or initially curved, and having any of the following:
   c.1. Diameter exceeding 3 inches and thickness exceeding 1.5 inches;
   c.2. Diameter exceeding 5 inches;
   c.3. Length and width both exceeding 3 inches and thicknesses exceeding 1.5 inches; or
   c.4. Length and width both exceeding 5 inches.

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One of the materials, specifically listed in the new BIS category 6A615, is zinc sulfide. SCHOTT has a method of manufacturing this material that differs from the manufacturing process controlled in the EAR. Through a Commodity Classification Determination in May of 2014, this material was deemed EAR99 by the U.S. Commerce Department, no license required to most destinations. **The new proposal, 6A615, appears to control this raw material in the blank form.**

Please note, that it is common practice for a company to list blanks in a range of sizes in their catalogue. Normally, these shapes and sizes of "non-controlled" material would not be subject to export controls, they are usually considered Commercial off the Shelf (COTS). Now, as we understand it, zinc sulfide material falling into the specific listed sizes in 6A615, would be considered controlled.

We believe that this material should be controlled at the component/part level, not at the blank level. We hope that DDTC will consider the following comments, and remove the specific language regarding these blanks from the new category 6A615.

Additional notes:

- The new proposal listing IR blanks appears to be contrary to the initial spirit of Export Control Reform. Rather than reduce the levels of control, it expands that control.
- U.S. Optical material manufacturers are presently working in an extremely competitive global marketplace.
    - **This material is readily available throughout the world.**
    - International Competition from foreign manufacturers in the U.S. for the commercial market.
    - Regarding U.S. government purchases, exemptions and value determinations in the "Buy America" act allow U.S. component manufacturers to buy their raw materials from international suppliers.
    - Now with the new ECR proposal regarding "blanks", international customers, who already have an aversion to filling out our end user certificates for components and parts, and who have gone so far as to design out U.S. export controlled materials, will now have to supply the same information for "blanks", and face licensing for raw materials. This new proposal will create a disincentive to potential international customers to deal with a U.S. company.
- There are also many markets for this material, other than military:

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- IR Microscopes/Telescopes
- Surveillance cameras
- Machine Vision
- Agricultural inspection(hyperspectral imaging)
- Medical imaging
- Building inspection windows for IR illumination of runways
- Electrical windows for switchgear inspection

We respectfully request that the specific language regarding the control of "blanks" be removed from the new category 6A615.

2. **The determination of the export control level of Image intensification Tubes is made more difficult with the new regulations.**

- SCHOTT is a manufacturer of components that can be used in concert with Image Intensification Tubes. We are not a system or image intensification tube manufacturer. The level of detail required to apply the new rules are burdensome for component manufacturer. A clearer delineation between what is an ITAR and EAR controlled would help greatly.

- While the new regulations in the ITAR do not make use of the "Special Designed" statement, the new corresponding EAR classification does:

  - **6A002 Optical sensors and equipment and ''components'' therefor, as follows (see List of Items Controlled).**

    Related Controls: (1) The following commodities are ''subject to the ITAR'' (see 22 CFR parts 120 through 130): (a) ''Image intensifiers'' defined in 6A002.a.2 and ''focal plane arrays'' defined in 6A002.a.3 ''specially designed,'' modified, or configured for military use and not part of civil equipment;

We respectfully request simplification of the delineation between ITAR and EAR controlled Image Intensification Tubes. These rules appear overly detailed, and as a result are extremely burdensome for a material, part and component manufacturer to apply.

General Comment Regarding the Export Control Reform.

We would like to also take this opportunity to make some general observations regarding the Export Control Reform initiative. We feel that it is important for DDTC to be aware of some of the issues that we have discovered since the beginning of ECR.

The new rules are not designed for material, component or part manufacturers, but for the manufacturer of end products.

1. Material, component and part manufacturers are at a strict disadvantage applying the new rules. The amount of information regarding the product end use required to make an export determination, in most instances, is not readily available to material, component and part

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manufacturers. To apply the new export control rules to a component or part, the customer must supply us with significant detail regarding:

i) What is the part, and what is it going to be used in ?
ii) The end use and performance parameters of the actual device (or component parts in that device).
iii) And now with Category XII, when the part will be incorporated into the device, in the United States, or outside of the U.S?

As a manufacturer of optical, fiber optic, and electronic packaging material, components and parts, we have to go back to the customer, sometimes more than once, for additional information. Some of this information was required in the past, but never at this level of detail. This places us at a disadvantage in the market place. Many, if not all of our parts, can be sourced outside of the United States. It is also fair to note that there are often legitimate reasons where a customer is unwilling to share detail with their suppliers, i.e., proprietary or competitive.

The number, specificity, and sometimes contradictory nature of the "notes" system, can be difficult to apply. For example, in CatXII, note to paragraph E, essentially states that an ITAR part is subject to the EAR, if it is included as an integral part of an item subject to the EAR, if it can't be removed without destroying it. If it is not yet incorporated, and it is shipped separately, it remains an ITAR controlled part. **How does a component manufacturer know if something can be removed from the end use without damaging it?**

2. For a manufacturer of materials, components and parts, making an export control determination simply takes longer, and is more difficult. All exporters, big or small, will have additional compliance costs, however, manufacturers of customer requested parts, components and materials in particular, will be working at a disadvantage. For this type of a manufacturer, every new order has potentially never been seen before, therefore creating a constant requirement for compliance review.

We appreciate the opportunity to comment on the new proposed rules. Hopefully our comments will contribute to a more beneficial system for everyone.

Thank you for your time and consideration.

SCHOTT North America Inc.,

James Purcell
International Trade Compliance Manager.
Empowered Official

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PUBLIC SUBMISSION

Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0004
Comment on DOS_FRDOC_0001-3226

Submitter Information

Name: Scott Snow

General Comment

I agree with the majority of these additions and more clear definitions of these items and military operating systems. I do not believe anything that can be found in common use by the majority of firearms owners should be more highly regulated. A small fragment of different optical finders and binocular gear could be more clearly defined and I believe adding an addendum or a not included in this list section are those items that can be purchased at a gun shop which are in active use by the majority of hunters or sport shooters. Now, most of the items listed, to include but not limited to the different missile systems, weapons systems computer software, and other types of laser guiding systems should be clearly defined as inappropriate to be owned by common civilians who are not employed in any type of military occupation.

Recommendations for the Proposed Modifications to Category XII

Readout Integrated Circuits (ROICs)

To date, ROICs for IRFPAs have not been controlled by ITAR. The proposed regulations would have a very confusing and chilling effect on domestic developments. Published papers and documents can not be taken out of circulation, patents unpublished, the Internet sanitized, or international contracts unilaterally modified. It is unrealistic and illogical for ROIC designs in open design, development, or production today to be treated under ITAR tomorrow.

The underlying ROIC technology, analog CMOS integrated circuit, has been around for over 40 years and is taught as part of most university electrical engineering curriculum around the world. International publications such as the IEEE Journal of Integrated Circuits and The International Society of Optics and Photonics, present the latest circuit and architectures for ROIC design. SPIE offers short course classes in ROIC design at international symposiums.

Foreign IRFPA competitors have clearly demonstrated ROIC design capability – witness the current wide assortment of very capable IRFPAs offered by nations across the globe. Some US designed ROICs are actually manufactured offshore (TSMC), while companies in Europe and Asia offer custom silicon design services including ROICs.

Further, and perhaps most damaging to US IRFPA capability, domestic semiconductor companies offering custom foundry services to fabricate ROIC wafers have little interest in imposing ITAR on their high volume highly competitive CMOS production lines just to process relatively few ROIC wafers leaving US IRFPA manufacturers, especially defense contractors looking for the most advanced capability, with few alternatives.

The preamble and selling points of the regulation change proposal highlight the changes to have little interference with commercial offerings, often using “specifically designed” as a key separation. In fact, the proposed regulations use the “specifically designed” designation for ROICs destined to be fabricated into IRFPAs. Unfortunately, this language has the opposite effect in this context as it encompasses ROICs “specifically designed” for commercial IRFPAs not intended for use as defense articles. As an example, the ROIC for Seek Thermal’s 206 X 156 pixel microbolometer IRFPA was designed, developed, and privately funded for the specific purpose of commercial thermal imaging. Yet at 32,136 pixels, the design exceeds the proposed limit of 19,200 pixels.

We recommend not adding ROIC control to the regulations by deleting proposed Category XII (e)(4) & (e)(5). Alternatively, if removal is found not to be acceptable, modifying Category XII (e)(4)(iii) to read:

“A microbolometer IRFPA having greater than ~~19,200~~ 787,000 elements”

to be consistent with the resolution of widely commercially available foreign IRFPAs.

Retaining the "specifically designed" designation, Category XII (e)(4) could be modified as follows:

"Read-Out Integrated Circuits (ROICs) specially designed for defense article application for an IRFPA controlled in paragraph (c)(2) of this category or detector elements therefor, as follows:"

In light of keeping our warfighters supplied with the most advanced capability, this option (or going forward with the proposed ROIC control regulations) handicaps US defense contractors in not being able to use the most advanced and economical production resources and is therefore not recommended.

"Permanent encapsulated sensor assembly"

With significant foreign commercial availability of IRFPAs, the requirement for a "*permanent encapsulated sensor assembly"* (Category XII (c)(2) and (5) and Note 1 to Paragraph C) is not necessary and should not be incorporated into export regulations.

The definition and specific requirements need clarification if this limitation is incorporated. We recommend that this definition allow for:

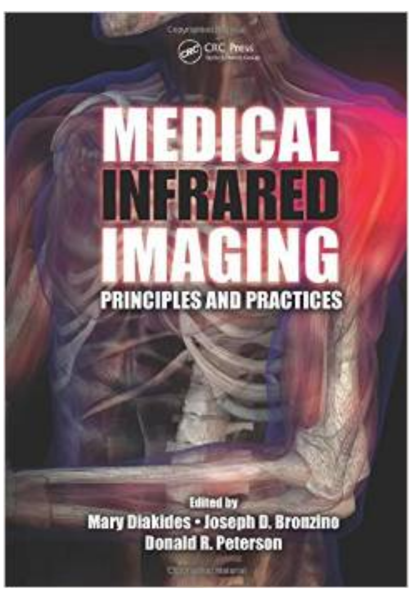
"permanently attaching a wafer level vacuum packaged IRFPA to a printed circuit board with associated electronics that makes the assembly inoperable if attempts to disassemble or tamper with the assembly are made."

Social and Economic Benefits of Thermal Imaging

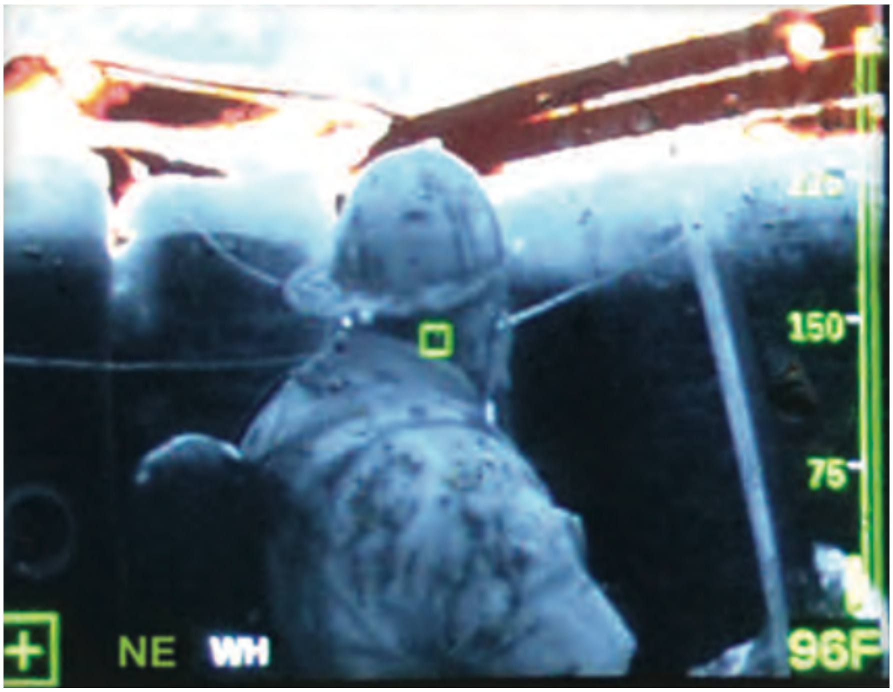
The social and economic benefits of thermal imaging outweigh any remaining US military advantage to be gained by continued export control of commercial microbolometer products. Let's take a look at why.

Thermal Imaging saves lives.
Thermal imaging has become an important tool in health and medicine. It has found applicability from cancer research to coronary bypass surgery. News articles tout thermal imaging as a meaningful aid in suppressing the current MERS epidemic.

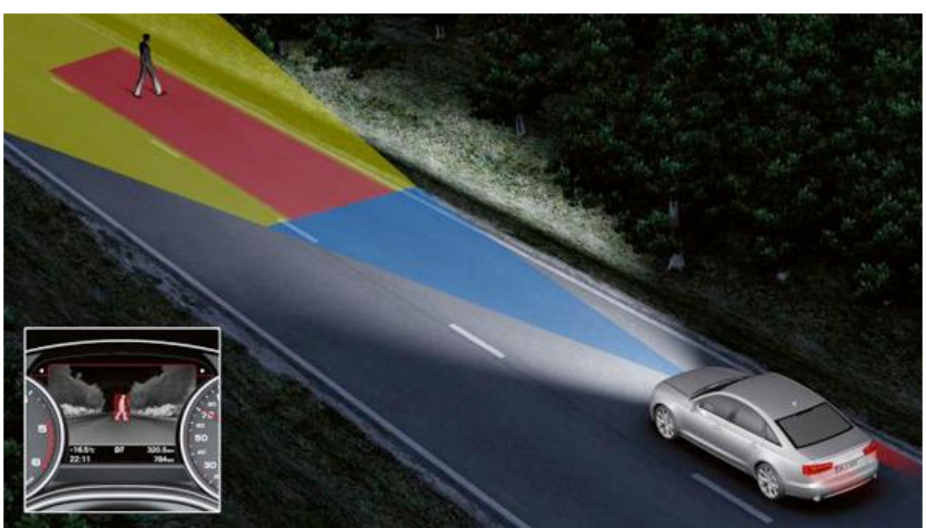
Passengers wearing masks to prevent contracting Middle East Respiratory Syndrome (MERS) walk past a thermal imaging camera (unseen) at Incheon International Airport in Incheon, South Korea, June 2, 2015. REUTERS/KIM HONG-JI



Firefighters around the globe consider the TIC (thermal imaging camera) as basic safety equipment. Introduced for firefighting aboard ships by the British Royal Navy in the 1970s, the technology allows the fireman to safely navigate in a rooms filled with smoke and in total darkness, often aiding lifesaving rescues. Search and rescue teams use handheld and airborne thermal cameras to locate the lost or injured in the wilderness or earthquake collapsed buildings. Thermal cameras were rushed to the scene of the 9/11 rescue operation.



Thermal imaging is big on the automotive safety roadmap. Moving from dash displays to autonomous warning and braking systems, thermal imaging systems will be helping to prevent tens of thousands of pedestrians from being killed each year in vehicle accidents worldwide. Thermal imaging will also be key to the prevention of the over one million collisions with deer we have in this country alone. Projections are by 2020, more than a million automobiles will be equipped with thermal night vision systems.



Thermal Imaging saves energy.
Seeing energy saves energy. The heat escaping from buildings is clearly low hanging fruit in the global mission to reduce energy usage. Our Department of Energy tells us nearly half of our total daily energy consumption in homes and commercial buildings is from heating or cooling which in turn represents a lion's share of the world's overall energy consumption. Thermal imaging is helping us to dramatically reduce the waste. A structural thermal survey, recommended by the DoE and mandated by our Euro-partners, finds the leaks that rob energy. Insulation deficiencies, poor weather stripping, and inadequate windows can easily be detected using a thermal imaging camera and thereby repaired.

By counting people in a room, a thermal imaging sensor can tune HVAC systems and save significant energy. Reducing heating/cooling of unoccupied areas will have a big effect on the world's energy appetite.

Incorporating appropriate optical filters and signal processing, a thermal infrared sensor can visualize natural gas. Leaking natural gas is an undesirable trifecta in today's society – a strong greenhouse gas, a dangerous and potentially explosive fire hazard, and, of course, a pricey wasted energy resource.

Thermal Imaging keeps us safe.
We all saw the capture of the Boston Bomber located by a helicopter mounted thermal camera while covered up by a tarp in the bottom of a parked boat.

Our security is improved by being able to detect intrusion especially at night using this technology. Police forces and local security companies are relying on the "people glow in the dark" nature of thermal imaging to provide protection and improve safety. With the recent dramatic cost reduction of this technology due to its adoption by the non-military world, thermal security cameras are now commonly installed to protect businesses and even residences. Whether a walk across a dark parking lot at night or why the dog is barking, a thermal camera can help keep us safe.

Thermal Imaging is making a better world.
Thermal imaging is another technology with global economic impact evolving from our military research– the next in line after commercial aircraft, computer chips, GPS, the Internet, and liquid crystal displays. The implications of thermal imaging are significant. Saving precious energy resources, dramatically improving preventative maintenance of high value equipment, crop monitoring of irrigation and fertilization from drones, security at night, food storage and preparation safety, and many other uses beyond contribute to a better tomorrow. Very low cost thermal imaging monitors are poised to be an important player in the Internet of Things. The positive impact of this technology on humanity is undeniable.

Thermal Imaging is a Global Technology
The thermal imaging industry itself will continue to generate billions in revenue providing jobs here in the United States, but only if we are not hamstrung in competing globally. Worldwide today, 9 out of 10 microbolometer thermal cameras are sold commercially. In 2019, just a few years away, that number will become 19 out of 20. [1] Global research investment from the commercial sector now far exceeds that of our military while worldwide microbolometer production capacity dwarfs any planned military deployment. Microbolometer arrays of commercial resolution and performance are currently being produced in foreign countries in both Europe and Asia and freely sold around the globe.

Restricting performance levels to less than foreign made devices (such as limiting picture updates to less than nine per second verses thirty of traditional television video) seriously handicaps US commercial suppliers competing in foreign markets. Foreign competitors are eager to make these differences very visible. Offered side by side next to more capable products of unconstrained offshore competitors in foreign marketplaces, *Made in the USA* is far less likely to be put in shopping carts.

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[1] Uncooled Infrared Imaging Technology & Market Trends, Yole Development, July 2014.

On the flip side, incorporation of commercial microbolometer arrays and sensor assemblies into foreign military equipment will not be curtailed by tough export regulations. Within our boarders, fully capability (array size, frame rate, sensitivity, etc.) matchbox size thermal imagers hang on sales hooks in hardware, sporting goods, online, and big box stores across the country, some priced as low as a couple of hundred dollars and sold by the hundreds of thousands, eventually millions, produced by both foreign and domestic manufacturers. At this level of consumer and industrial proliferation, control becomes pointless.

Export policy needs to be visionary as technology is hardly static. Advancements in just one or two years are often dramatic. Waiting for foreign transfer of technology from research labs to production before making a protracted review of export regulations is akin to politely asking the rest of the world to take the lead. Without exportability, the economics just don't justify investment to keep ahead or even keep up. Commercial investment at home to develop the next "new and improved" will not occur until there is a dependable worldwide level playing field to compete.

ITAR can easily cripple our domestic capability. Today, readily accessible high volume semiconductor microelectronic manufacturers both here and abroad offer custom foundry services to produce wafers of silicon integrated circuits used as the starting substrate in the fabrication of microbolometer sensors. Placing ITAR on the design and production of silicon wafers designed for commercial (or military) microbolometer fabrication would be acknowledged by a "no-bid" from these manufacturers. Microbolometer silicon "readout integrated circuit" (ROIC) business volumes are minuscule compared to other traditional consumer, automotive, and industrial microelectronic production. Asking semiconductor companies to impose ITAR compliance on these very large and highly competitive production lines is unrealistic. Although today the technology level required for these devices can be fabricated by foundries domestically, as microbolometer technology progresses, more technologically advanced silicon fabrication will be necessary. Unfortunately, custom design foundry services for the most advanced production processes have moved to Asia - clearly a real pickle in developing future generations of advanced microbolometer sensors under ITAR.

There is foreign availability of these microbolometer silicon readout circuits (ROICs). Foreign IRFPA competitors have clearly demonstrated ROIC design capability – witness the current wide assortment of very capable IRFPAs offered by nations across the globe. This technology is publically well documented in published literature and patents. Foreign design houses accept contracts for new custom designs.

By encumbering export of microbolometer arrays, sensors, and cameras from the United States, our narrow technical leadership will be readily overtaken. Ironically, this results in looking to foreign supply to fill our military needs with the most advanced and economical technology. We only need to ask where the other electronic components in our tanks, ships, and aircraft are being produced. This country owes itself an unobstructed opportunity to compete worldwide in a technology that has such broad and compelling social and economic benefit.

SEILER

VIA EMAIL: DDTCPublicComments@state.gov

July 01, 2015

Department of State
Office of Defense Trade Controls Policy

ATTN: Regulatory Change, USML Category XII

COMPANY BACKGROUND

Seiler Instrument & Manufacturing Company, Inc. (Seiler) is a United States Company that manufactures a variety of defense-related products including the optical-mechanical fire control and sighting systems used on certain Howitzer and Mortar systems. See attached "Guide to Optical Fire Control for Howitzers and Mortars" for examples of the products that Seiler manufactures. Seiler is a registrant with the DDTC pursuant to ITAR 122 and considers many of its products to be controlled under USML Category XII.

SUMMARY

We are asking for clarity with respect to the types of equipment included within the scope of revised USML Category XII(a)(1) and but that do not fall within the scope of either XII(a)(2) or XII(a)(3). This distinction is important since revised USML Category XII(a)(1) controls "specially designed parts and components" in addition to the enumerated "systems or equipment" whereas revised XII(a)(2) and XII(a)(3) do not.

Seiler interprets this to mean that "specially designed parts and components" of revised USML Category XII(a)(1) "systems or equipment" remain under the jurisdiction of the ITAR (though now as Significant Military Equipment) while "specially designed parts and components" of revised XII(a)(2) or XII(a)(3) "systems or equipment" will transfer to the jurisdiction of the EAR under ECCN 6A615, unless otherwise enumerated in revised XII.

Therefore, in order to determine jurisdiction of USML Category XII(a) "specially designed parts and components", it is essential to know with certainty which specific paragraph enumerates the parent "systems or equipment".

SEILER INSTRUMENT AND MANUFACTURING COMPANY, INC.
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(800) 489-2282 • (314) 968-2282 • www.seilerinst.com

SPECIFIC ISSUE

Within the current vernacular the term "fire control" is used somewhat broadly and, as applied to such systems as howitzers and mortars, encompasses the optical weapon sights and related mounts and attachments in addition to the computerized systems designed to target and coordinate fire.

Therefore it is unclear, within the revised regulation, how USML Category XII(a)(1) "Fire control systems or equipment" are distinct from USML Category XII(a)(2) "weapon sights" or "weapon aiming systems" and USML Category XII(a)(3) "electronic or optical positioning, laying, or spotting systems". This lack of clarity will result in confusion in this industry over the jurisdiction of the related "specially designed parts and components" [i.e. those associated with XII(a)(1) systems being ITAR controlled; those associated with XII(a)(2) or XII(a)(3) being CCL controlled] and the significant expense of preparing commodity jurisdiction requests by all parties necessary in order to resolve that confusion. This result is contrary to one of the stated objectives of the revision to USML Category XII: "to establish a 'bright line' between the USML and the CCL for the control of these articles".

As an example, Seiler is not sure how to classify much of the equipment pictured in the attached "Guide to Optical Fire Control for Howitzers & Mortars" within the revised USML Category XII. Are these systems elements of "fire control" [XII(a)(1)]? Or are these elements of "weapon sights" or "weapon aiming systems" [XII(a)(2)]? Or are these elements of "weapon positioning systems" [XII(a)(3)]? These proposed USML Category XII sections are not sufficiently clear nor mutually exclusive enough to allow for the specific and confident classification of many of these types of systems.

RECOMMENDATION

The revised USML Category XII(a)(1) should provide a clear and "bright line" definition of the articles controlled under the term "fire control systems or equipment" and how those articles are distinct from those controlled under USML Categories XII(a)(2) and (3). This is essential in order for industry to properly determine the jurisdiction of the related "specially designed parts and components" since they are treated differently under XII(a)(1) vs. XII(a)(2) or XII(a)(3).

Thank you for your consideration.

Sincerely,

Richard Gray
VP Information Systems
Empowered Official

GUIDE TO OPTICAL FIRE CONTROL FOR HOWITZERS & MORTARS

SEILER
MANUFACTURING DIVISION

Manufacturing Division
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Seiler is the Original Equipment Manufacturer for the optical fire control used on all United States howitzer and mortar systems. Seiler machines, assembles, and tests all of our products for the United States Government, military contractors, and both public and private enterprises.

Within our expertise of machining, assembly, and testing capabilities, Seiler also specializes in the inspection, repair, overhaul, and refurbishment of the artillery fire control used on all existing United States howitzer systems as well as many howitzer systems used by our allies. Refurbished fire control can extend the life of your weapon system at a fraction of the cost to replace the damaged or depreciated instrument.

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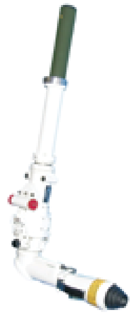
M109

M109 SERIES, 155MM SP HOWITZER



ELBOW TELESCOPE M118A2
NSN: 1240-01-092-2693
P/N: 11829207

TELESCOPE MOUNT M146
NSN: 1240-00-864-0348
P/N: 8616011

PERISCOPE M42
NSN: 1240-00-864-2933
P/N: 7645543

PANTEL M117A2
NSN: 1240-00-106-7754
P/N: 11739510

PANTEL MOUNT M145A1
NSN: 1240-01-313-6842
P/N: 8267701-1

ALIGNMENT DEVICE M140A1
NSN: 4931-01-472-6622
P/N: 11741648-4

M777

M172A1 TELESCOPE MOUNT
NSN: 1240-01-517-2171
P/N: 13005089

M138A1 ELBOW TELESCOPE
NSN: 1240-01-515-8264
P/N: 13005104

M18A1 FIRE CONTROL QUADRANT
NSN: 1290-01-515-8262
P/N: 13005102

M171A1 TELESCOPE MOUNT
NSN: 1240-01-515-8265
P/N: 13005103

M137A2 PANORAMIC TELESCOPE
NSN: 1240-01-277-0472
P/N: 12984713

M17A1 FIRE CONTROL QUADRANT
NSN: 1240-01-515-8260
P/N: 13005101

ALIGNMENT DEVICE M154
NSN: 4931-01-516-1430
P/N: 11741648-5

M198

M172A1 TELESCOPE MOUNT
NSN: 1240-01-517-2171
P/N: 13005089

M138A1 ELBOW TELESCOPE
NSN: 1240-01-038-0530
P/N: 13005104

M18A1 FIRE CONTROL QUADRANT
NSN: 1290-01-515-8262
P/N: 13005102

M171A1 TELESCOPE MOUNT
NSN: 1240-01-515-8265
P/N: 13005103

M137A3 PANORAMIC TELESCOPE
NSN: 1240-01-483-6100
P/N: 12984775

M17A1 FIRE CONTROL QUADRANT
NSN: 1290-01-515-8260
P/N: 13005101

ALIGNMENT DEVICE M139A1
NSN: 4931-01-472-6621
P/N: 11741648-3

M119

M119 LIGHT WEIGHT HOWITZER

M186 TELESCOPE MOUNT
NSN: 1240-01-277-0473
P/N: 12599175

M90A3 STRAIGHT TELESCOPE
NSN: 1240-01-480-0292
P/N: 12984673

M187 TELESCOPE MOUNT
NSN: 1240-01-483-5324
P/N: 12984689

M137A2 PANORAMIC TELESCOPE
NSN: 1240-01-277-0472
P/N: 12984713

ALIGNMENT DEVICE M140A1
NSN: 4931-01-472-6622
P/N: 11741648-4

M110A2

M110A2 HEAVY, SELF PROPELLED HOWITZER, 8”

M137 TELESCOPE MOUNT
NSN: 1240-00-895-6492
P/N: 8587295

M115 PANORAMIC TELESCOPE
NSN: 1240-00-895-9186
P/N: 8587340

M138 TELESCOPE MOUNT
NSN: 1240-00-896-2240
P/N: 8587500

M16A1D ELBOW TELESCOPE
NSN: 1240-00-759-7781
P/N: 7597781

ALIGNMENT DEVICE M140A1
NSN: 4931-01-472-6622
P/N: 11741648-4

M110A1

M16A1D ELBOW TELESCOPE
NSN: 1240-00-759-7781
P/N: 7597781

M23 TELESCOPE MOUNT
NSN: 1240-00-757-8441
P/N: 7578441

M12A7S PANORAMIC TELESCOPE
NSN: 1240-00-917-6433
P/N: 8213037

M21A1 TELESCOPE MOUNT
NSN: 1240-00-757-8596
P/N: 7578396

M4A1 FIRE CONTROL QUADRANT
NSN: 1290-00-674-0765
P/N: 6740765

M102

ELBOW TELESCOPE M114A1
NSN: 1240-00-150-8889
P/N: 11730285

M14 FIRE CONTROL QUADRANT
NSN: 1290-00-066-4994
P/N: 8626310

M113A1 PANORAMIC TELESCOPE
NSN: 1240-00-150-8886
P/N: 11730267

M134A1 TELESCOPE MOUNT
NSN: 1240-00-150-8890
P/N: 10553215

ALIGNMENT DEVICE M140A1
NSN: 4931-01-472-6622
P/N: 11741648-4

EFS120MM

120MM M137 TOWED RIFLED MORTAR SYSTEM

M67A1 SIGHT UNIT
NSN: 1015-01-556-1178
P/N: SLB10821

- M67A1 MOUNT

NSN: 1240-01-556-1188
P/N: SLB10804

- M67A1 ELBOW TELESCOPE

NSN: 1240-01-556-1187
P/N: SLB10430

M45E1 BORESIGHT
NSN: 1240-00-152-3512
P/N: 10549221

120MM

120MM M120/M121 MORTAR SYSTEM

M67 SIGHT UNIT
NSN: 1240-01-366-7322
P/N: 9356182

- M67 MOUNT
NSN: 6650-01-340-6082
P/N: SLB10804

- M67 ELBOW TELESCOPE
NSN: 6650-01-341-5195
P/N: 9356181

M45E1 BORESIGHT
NSN: 1240-00-152-3512
P/N: 10549221

81MM

81MM M252 MORTAR SYSTEM

M45E1 BORESIGHT
NSN: 1240-00-152-3512
P/N: 10549221

M64 SIGHT UNIT
NSN: 1240-01-379-7953
P/N: 99360168

- M64 MOUNT
NSN: 1240-01-201-8299
P/N: 9360169

- M64 ELBOW TELESCOPE
NSN: 1240-01-211-3608
P/N: 9360257

M67 SIGHT UNIT
NSN: 1240-01-366-7322
P/N: 9356182

- M67 MOUNT
NSN: 6650-01-340-6082
P/N: SLB10804

- M67 ELBOW TELESCOPE
NSN: 6650-01-341-5195
P/N: 9356181

60MM

60MM M224 MORTAR SYSTEM

M45E1 BORESIGHT
NSN: 1240-00-152-3512
P/N: 10549221

M64 SIGHT UNIT
NSN: 1240-01-379-7953
P/N: 99360168

- M64 MOUNT

NSN: 1240-01-201-8299
P/N: 9360169

- M64 ELBOW TELESCOPE

NSN: 1240-01-211-3608
P/N: 9360257

M67 SIGHT UNIT
NSN: 1240-01-366-7322
P/N: 9356182

- M67 MOUNT

NSN: 6650-01-340-6082
P/N: SLB10804

- M67 ELBOW TELESCOPE

NSN: 6650-01-341-5195
P/N: 9356181

HANDLE & FIRING MECHANISM
NSN: 1010-01-043-2050
P/N: 11578985

RANGE INDICATOR
NSN: 5840-01-458-6159
P/N: 9360374

RANGE INDICATOR KIT
NSN: 1010-01-237-9033
P/N: 9360382

SUPPORTING EQUIPMENT FOR HOWITZERS AND MORTARS

M2A2 AIMING CIRCLE WITH EQUIPMENT
NSN: 6675-01-067-0687
P/N: 11785090

M24 TRIPOD
NSN: 1290-00-346-8184
P/N: 8242777

GUNNER’S QUADRANT M1A1
NSN: 1290-00-891-9999
P/N: 7197156

M58/M59 AIMING POST LIGHT
NSN: 1290-00-169-1934
1290-00-169-1935
P/N: 11730975/11730976

M14 AIMING POST LIGHT
NSN: 1290-01-509-2714
P/N: SLB10530/13010087

COLLIMATOR M1A2
NSN: 1240-01-465-5452
P/N: 12984644

CROSS LEVELING FIXTURE
NSN: 6650-00-652-3553
P/N: 6523553

AZIMUTH TEST FIXTURE
NSN: 4931-00-769-1596
P/N: 7691596

M3 BORESCOPE
NSN: 6650-01-063-0035
P/N: 11584701

ELEVATING MECHANISM
NSN: 1015-01-414-6269
P/N: 11580034

TRAVERSING MECHANISM
NSN: 1015-01-414-7493
P/N: 11579980

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July 6, 2015

Ms. Hillary Hess
Director
Regulatory Policy Division
Room 2099B
Bureau of Industry and Security
U.S. Department of Commerce
14th Street & Pennsylvania Ave., N.W.
Washington, D.C. 20230

Mr. Ed Peartree
Director
Office of Defense Trade Controls Policy
U.S. Department of State
2401 E Street, N.W.
Washington, D.C. 20037

Re: Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the United States Munitions List (USML) (*Federal Register* Notice of May 5, 2015; RIN 0694-AF75) and Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII (*Federal Register* Notice of May 5, 2015; RIN 1400-AD32)

Dear Ms. Hess and Mr. Peartree:

The Semiconductor Industry Association ("SIA") is the premier trade association representing the U.S. semiconductor industry. Founded in 1977 by five microelectronics pioneers, SIA unites over 60 companies that account for nearly 90 percent of American semiconductor production and the semiconductor industry accounts for a sizeable portion of U.S. exports.

SIA is pleased to submit the following public comments in response to the request for public comments issued by the Commerce Department's Bureau of Industry and Security ("BIS") on proposed revisions to the Export Administration Regulations ("EAR") pertaining to items the President determines no longer warrant control under United

States Munitions List ("USML") Category XII ("Proposed EAR Revisions"),[1] and revisions to the USML Category XII ("Proposed ITAR Revisions").[2]

I. Summary

As the notes to Category XII underscore, a clear and straightforward definition in the International Traffic in Arms Regulations (ITAR) of the term "directly related" is needed. SIA recommends a definition that closely adheres to the natural meaning of the words: "required and peculiarly responsible for the controlled features of the associated item." Such a definition could utilize the definition of "required" and "peculiarly responsible" as contained in the pending Commerce Department regulatory proposal. It should be construed in a manner at least consistent with the ITAR definition of "specially designed." Among other things, this would mean that software is not "directly related" to a defense article if the software has equivalent performance, characteristics or functionality to software that can be used in or with a civilian article.

The proposed revision to Export Control Classification Number ("ECCN") 6A002 stating that certain "space qualified" devices are subject to ITAR control runs directly counter to the overall thrust of the President's Export Control Reform Initiative ("ECRI"), as it would necessarily and without justification take items currently subject to EAR control and render them subject to ITAR control.

Classifying an unfinished civilian good as subject to ITAR control when the finished good is subject to EAR control is illogical and has serious adverse implications for semiconductor devices. The properties and capabilities of a focal plane array that is not in a "permanent encapsulated sensor assembly" are identical to those of a focal plane array that is in a "permanent encapsulated sensor assembly." Any distinction between those products is based purely on form, not substance, and for that reason should not affect national security sensitivities.

The proposed rule would prohibit exporters from using License Exception STA for any item covered by several different ECCNs. Licensing flexibility that is useful to industry should not be eliminated unless there is a compelling reason to do so.

II. Proposed ITAR Changes

A. Definition of "Directly Related"

No definition of the term "directly related" currently exists in the International Traffic in Arms Regulations ("ITAR"). Moreover, SIA is disappointed that no definition of

[1] Revisions to the Export Administration Regulations (EAR): Control of Fire Control, Range Finder, Optical, and Guidance and Control Equipment the President Determines No Longer Warrant Control Under the United States Munitions List (USML), 80 Fed. Reg. 25,798 (May 5, 2015) ("Proposed EAR Revisions").

[2] Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII, 80 Fed. Reg. 25,821 (May 5, 2015) ("Proposed ITAR Revisions").

that term has been proposed by the State Department in its harmonization proposal.[3] Given the importance of "directly related" in determining the types of technical data, software and defense services subject to ITAR control,[4] a definition of "directly related" within the ITAR has been sorely needed. A clear and straightforward definition of "directly related" should be promulgated that adheres closely to the natural meaning of the words, *i.e.*, "required and peculiarly responsible for the controlled features" of the associated item.

As part of the President's Export Control Reform Initiative ("ECRI"), several years of effort have gone into formulating a definition of "specially designed." While the "specially designed" definition applies throughout the Commerce Control List ("CCL") administered under the EAR, it is generally used with respect to hardware on the USML. For the same reason that a "specially designed" definition was needed to clarify ITAR controls on hardware, a counterpart and correlative definition of "directly related" -- an even more ambiguous and elastic term than "specially designed" -- is needed to clarify ITAR controls on technical data, software and services.

While the State Department is proposing a long overdue amendment to the controls on software (by making software a defense article, rather than technical data), "directly related" is likely to continue to play a significant role in determining controls on technical data, software and defense services. First, any technical data "directly related" to ITAR software will necessarily be "directly related" to a defense article and thus controlled. Second, the State Department has indicated that it will add catch-all categories covering software to various USML categories[5] and those new software catch-all categories likely will include "directly related" as a control criterion.

The term "directly related," is applied in the proposed rulemaking for USML Category XII. Specifically,

- In proposed Note 1 to paragraph (f) of USML Category XII, the State Department states that technical data and defense services "directly related" to various defense articles controlled in other paragraphs of USML Category XII "remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR."

- In proposed Note 2 to paragraph (f) of USML Category XII, the State Department states that software that converts a defense article into an item subject to the EAR or that converts an item subject to the EAR into a defense article is "directly related" to the defense article.

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[3] International Traffic in Arms: Revisions to Definitions of Defense Services, Technical Data, and Public Domain; Definition of Product of Fundamental Research; Electronic Transmission and Storage of Technical Data; and Related Definitions, 80 Fed Reg. 31525 (Jun. 3, 2015) ("ITAR Harmonization Definitions")

[4] *See*, *e.g.*, Temporary Modification of Category XI of the United States Munitions List, 80 Fed. Reg. 37,974, 37,975 (Jul. 2, 2015).

[5] ITAR Harmonization Definitions at_ 31,527.

The scope attached to "directly related" in these proposed notes is detached from any plain meaning of the term.

The guidance provided in proposed Note 1 to paragraph (f) of USML Category XII indicates that technical data not "specially designed" for a defense article nonetheless is directly related to the defense article. Such an overly broad reach of "directly related" is misguided and does violence to the plain meaning of the term. If certain technical data apply equally to items subject to the EAR as to items subject to the ITAR, then the technical data necessarily, under the recently promulgated "specially designed" definition, are not "specially designed" for defense articles, and so should not be deemed "directly related" to any defense article. "Directly related" should not be taken to mean merely "capable of use with." Both the State and Commerce Departments explicitly repudiated the "capable of" standard in their definition of "specially designed."[6] That over-reaching standard should not be embedded in "directly related."

The guidance provided in proposed Note 2 to paragraph (f) of USML Category XII indicates that software is directly related to a defense article if the software converts the defense article into an item subject to the EAR. Software that converts a defense article into an item subject to the EAR necessarily infuses the article with characteristics that do not warrant control under the ITAR. Such software should not be deemed "directly related" to a defense article. "Directly related" as it pertains to software should at least have the limitations contained in the definition of "specially designed." Currently, software is subject to both terms, compounding the uncertainty and confusion.

A definition of "directly related" is needed in order to clarify the export control status of myriad technical data used in or with both defense articles and items subject to the EAR as well as with respect to software. A definition of "directly related" should be promulgated that adheres closely to the natural meaning of the words, *i.e.*, "required and peculiarly responsible for the controlled features" of the associated item. Both "required" and "peculiarly responsible" have commonly understood definitions among the exporting public and those commonly-understood definitions should apply in this context. Alternatively, those terms could be assigned meanings similar to those currently being proposed by the State and Commerce Departments.[7]

Software or technical data that is not peculiarly responsible for the controlled feature(s) of a defense article should not be deemed "directly related" to the defense article even if the software or technical data are used in the design and production of the defense article. For example, a semiconductor producer may receive a defense customer's own proprietary Read Only Memory ("ROM") software code that would be used to produce a specific or custom ROM-coded version of a commercial microcontroller for its defense

[6] Amendment to the International Traffic in Arms Regulations: Initial Implementation of Export Control Reform, 78 Fed. Reg. 22744 (Apr. 16, 2013); "Specially Designed: Definition, 77 Fed. Reg. 36410 (Jun. 19, 2012).

[7] Revisions to Definitions in the Export Administration Regulations, 80 Fed. Reg. 31,505, 31,519 (Jun. 3, 2015); ITAR Harmonization Definitions at 31,535-36

customer. Such custom ROM-coded microcontrollers are "specially designed" for the defense customer's ITAR-controlled equipment, and the customer's proprietary software ROM code should be deemed "directly related" to the customer's defense article because that software is peculiarly responsible for the controlled features of both the "specially designed" microcontrollers and the defense article. In contrast, other software or technical data used to produce the ROM-coded devices should not be considered "directly related" to those devices or the defense article because those other software and technical data, while used in the design and production of the custom ROM- coded devices, are not peculiarly responsible for the controlled feature of either the "specially designed" devices or the defense article. Instead, that other software and technical data relate to the commercial microcontroller underlying the ROM-coded device produced for the defense customer and so do not warrant designation as being "directly related" to a defense article. The only software that is directly related to the defense article (the ROM-coded microcontroller) in this example is the defense customer's proprietary software code.

Lastly, it should be made clear that software is not "directly related" to a defense article if the software has equivalent performance, characteristics or functionality to software that can be used in or with a civilian article. Such software is too broadly related to defense and civilian articles to be ***directly*** related to a defense article.

B. Proposed USML Category XII(c)(2)

As currently drafted, proposed USML Category XII(c)(2) will cover (among other things):

> {P}hoton detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor.[8]

No limit is placed on the number of detector elements included in microbolometer IRFPAs covered by this proposed USML category. In contrast, proposed USML Category XII(c)(5), which pertains to microbolometer IRFPAs integrated into a permanent encapsulated sensor assembly, covers only those microbolometer IRFPAs having greater than 328,000 detector elements.[9]

Microbolometer IRFPAs with fewer than 328,000 detector elements commonly are being used in civilian end uses. In particular, original equipment manufacturers ("OEMs") are developing cameras to meet automotive manufacturers' ever-increasing demand for automotive systems that enhance driving safety, and such cameras frequently include microbolometer IRFPAs with fewer than 328,000 detector elements, but peak responses within the wavelength range between 900 nm and 30,000 nm. It would be inappropriate

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[8] Proposed ITAR Revisions at 25,826.

[9] Id.

and counterproductive to U.S. economic competitiveness[10] for the State Department to impose ITAR controls on microbolometer IRFPAs that are used in civilian end uses. Moreover, there is no valid justification for the State Department to limit the scope of controls on microbolometer IRFPAs incorporated into permanent encapsulated sensor assemblies in a different manner than it limits the scope of controls on microbolometer IRFPAs not incorporated into permanent encapsulated sensor assemblies. The properties and capabilities of a focal plane array that is not in a permanent encapsulated sensor assembly are identical to those of a focal plane array that is in a permanent encapsulated sensor assembly. Any distinction between those products is based purely on form, not substance, and for that reason should not affect national security sensitivities.

Accordingly, the State Department should revise proposed USML Category XII(c)(2) as follows:

> {P}hoton detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm **and greater than 328,000 detector elements,** and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor

Such a revision would largely, if not entirely, eliminate the capture by this USML category of devices for civilian end uses, and so would comport with the stated intent of the U.S. government.

C. Proposed USML Category XII(c)(7)

As currently drafted, proposed USML Category XII(c)(7) will cover:

> Charge multiplication focal plane arrays having greater than 1,600 elements in any dimension and having a maximum radiant sensitivity exceeding 50 mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, and avalanche detectors therefor[11]

This level of control would sweep in image sensors that are incorporated in high volume civil applications such as automobile onboard day/night cameras for road safety, electronic toll collection for Intelligent Traffic Systems, digital pathology solutions in the medical field, scientific instruments used in astronomy and microscopy, and surveillance cameras used in parking lots or inside banks. As sensor prices continue to decline and complementary technologies (such as the "Internet of Things") increase the value of sensors, the volumes for these civil applications will increase exponentially.

---

[10] U.S. developers of microbolometers IRFPAs for automotive OEMs compete directly and intensely with European developers of microbolometers IRFPAs having the same characteristics and performance capabilities, none of which are subject to European military export controls.

[11] ITAR Revisions at 25826.

In addition, there is both foreign competition from image sensors meeting the proposed control parameters but not subject to similar controls, and competing technology that serves these markets but is not covered under the proposed control parameters.

Given the rapidly growing commercial applications for low light imaging sensors and alternative technologies in the market, charge multiplication focal plane arrays should remain on the EAR and not be moved to the ITAR.   Alternatively, if charge multiple focal plane arrays are to be controlled in a new USML Category XII(c)(7), that USML category should be revised as follows:

> Charge multiplication focal plane arrays having ~~greater than 1,600 elements in any dimension and~~ ~~having~~ a maximum radiant sensitivity exceeding ~~50~~ **250**mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, **and average radiant sensitivity exceeding 175 mA/W within the same spectral region of interest** and avalanche detectors therefor

Such a revision would largely eliminate the capture by this USML category of devices for civilian end uses, and so would comport with the stated intent of the U.S. government.

III. Proposed EAR Changes

A. ECCN 6A002

1. Related Controls Note

Among the proposed revisions to Export Control Classification Number ("ECCN") 6A002 is a new *Related Controls* discussion, part (1) (b) of which states that "space qualified" solid-state detectors, "space qualified" imaging sensors and "space qualified cryocoolers defined in 6A002.a.1, 6A002.b.2.b.1 and 6A002.d.1, respectively, are subject to ITAR control.[12] That proposed change runs directly counter to the overall thrust of the President's Export Control Reform Initiative ("ECRI"), as it would necessarily and unambiguously take items currently subject to EAR control and render those items subject to ITAR control. No justification is provided for doing so.

To be clear, no modification is proposed to the definitions contained in 6A002.a.1, 6A002.b.2.b.1 and 6A002.d.1. Instead, items currently within those ECCNs would simply be moved to the ITAR. SIA understands that re-classifying products clearly and unambiguously subject to the EAR to the U.S. Munitions List ("USML") is contrary to the purpose of the ECRI.

[12] Proposed EAR Revisions at 25,811.

2. Note 3 to 6A002.a.3

Among the proposed revisions to 6A002.a.3 is a new Note 3 stating that non-"space qualified" focal plane arrays that are not in a "permanent encapsulated sensor assembly" subject to the EAR are "subject to the ITAR."[13] The term "permanent encapsulated sensor assembly" is defined as

> {A} permanent encapsulated sensor assembly (e.g. sealed enclosure, vacuum package) containing an infra-red focal plane array (IRFPA) that prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.[14]

This proposed EAR revision would subject unfinished and semi-finished goods to ITAR control, notwithstanding that if the goods were finished they would not be subject to ITAR control.

This approach -- classifying an unfinished civilian good as subject to ITAR control when the finished good is subject to EAR control – is illogical and has serious adverse implications for semiconductor devices. As noted above, the properties and capabilities of a focal plane array that is not in a "permanent encapsulated sensor assembly" are identical to those of a focal plane array that is in a "permanent encapsulated sensor assembly." Any distinction between those products is based purely on form, not substance, and for that reason should not affect national security sensitivities.

Accordingly, BIS should remove Note 3 to ECCN 6A002.a.3.

B. License Exception STA

If implemented, the proposed rule would prohibit exporters from using License Exception STA for any item covered by several different ECCNs.[15] No justification is provided for this proposed limitation on the use of License Exception STA. Licensing flexibility that is useful to industry should not be eliminated unless there is a compelling reason to do so.

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[13] Proposed EAR Revisions at 25,812.

[14] Proposed EAR Revisions at 25,810.

[15] EAR Revisions at 25,800-01, 25,809

SIA appreciates the opportunity to comment on the Proposed Revisions and looks forward to continuing its cooperation with the U.S. Government on export control reform. Please feel free to contact the undersigned or Joe Pasetti, Director of Government Affairs at SIA, if you have questions regarding these comments.

Mario R. Palacios

Cynthia Johnson
Co-Chair, SIA Export Control Committee

Mario R. Palacios
Co-Chair, SIA Export Control Committee

From:	Bank, Seth R
To:	DDTCPublicComments
Subject:	ITAR Amendment—Category XII
Date:	Tuesday, July 07, 2015 3:00:36 PM

To Whom it May Concern:

The University of Texas is very hesitant to purchase any ITAR restricted items as restricting their access to foreign graduate students is onerous, if not nearly impossible. As a Principal Investigator, it would be impossible for me to justify the purchase of a scientific tool that could not be used by many of my students.

It would be especially devastating for the photonics research community if the US government were to place ITAR restrictions on scientific grade cameras, such as intensifier CCD, near infrared InGaAs and EMCCD cameras. If this were to happen, it will setback US research significantly, especially, in contrast to the research in EU and Asia have no such restrictions exist from their respective Governments.

Please do not hesitate to contact me by phone (512-471-9669) or email (sbank@ece.utexas.edu) if I may be of any assistance in this matter.

Best regards,
Seth

Seth R. Bank
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Department of State Proposed Rule
Amendment to the International Traffic in Arms Regulations:
Revision of U.S. Munitions List Category XII (RIN 1400-AD32)

Comments of Small UAV Coalition

Filed via email to DDTCPublicComments@state.gov

The undersigned, on behalf of the Small UAV Coalition, hereby comments on the proposed rule published on May 5, 2015, 80 Fed. Reg. 25821.

Members of the Small UAV Coalition[1] share an interest in advancing regulatory and policy changes that will permit the operation of small UAVs in the near term, within and beyond the line of sight, with varying degrees of autonomy, for commercial, consumer, recreational and philanthropic purposes.

Our detailed comments are provided below. As a general proposition, the Coalition does not believe that LiDAR (light detection and ranging) systems manufactured and used solely for civil commercial operations of small unmanned aerial vehicles and systems ("UAV", "UAS") should be subject to the ITAR. LiDAR systems are now widely used by UAS operators for purposes of situational awareness and collision avoidance. Commercial markets in the U.S. and around the world now dominate and in the future will continue to dominate the sale of this technology for use with UAS. The Coalition expects that such technology will be included in many thousands of UAS and employed in conducting a wide variety of civil and commercial operations both in the United States and in foreign countries. Far from being designed or intended for military application, the UAS with a LiDAR system will save time, save money, and even save lives, as the Federal Aviation Administration ("FAA") has found.[2] Tasks now being conducted by manned helicopter or fixed-wing aircraft, or by persons on the ground using a ladder or other device, will be replaced with the safer operations of a small UAS.

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[1] Members of the Small UAV Coalition include 3D Robotics, Aerialtronics, AirMap, Airware, Amazon Prime Air, Botlink, DJI Innovations, DroneDeploy, EHang, Flirtey, Intel, HAZON Solutions, InterMedia Development Corporation, Google[x] Project Wing, GoPro, Kespry, Parrot, PrecisionHawk, SkyPan, Sky-Futures, SkyWard, Strat Aero, Verifly, and Zero Tech.

[2] Operation and Certification of Small Unmanned Aircraft Systems (Feb. 23, 2015), 80 Fed. Reg. 9544, at 9547-8, 9578 (preamble to Notice of Proposed Rulemaking).

By FAA definition in its Small UAS Notice of Proposed Rulemaking, small UAVs weigh no more than 55 pounds, generally may fly in Class G airspace below 500 feet Above Ground Level ("AGL"), and generally must be flown at a certain distance from airports unless the operation is cleared by the airport manager or Air Traffic Control. They currently operate pursuant to an FAA exemption under section 333 of the FAA Modernization and Reform Act or a Certificate of Authorization (for public agencies). We expect the final rule adopted by the FAA within the next year or so will retain these basic conditions.

The Coalition is concerned that the proposed inclusion on the United States Munitions List ("USML") of LiDAR systems that are used with small UAS will significantly reduce the safety and efficiency benefits of commercial and civil UAS operations and will simply drive manufacturers to other countries.

In the United States, the Departments of State and Commerce agreed, as part of the President's Export Control Reform effort, on a common definition of "specifically designed" in order to clarify and simplify the distinction between military and dual-use items. The current USML Category XII utilizes this definition to ensure that only those items "specifically designed" for military application are captured on the USML. For example, USML Category XII(b) covers "lasers, *specifically designed*, modified or configured *for military application* . . . .", while Category XII(e) covers "components, parts, accessories, attachments and associate equipment *specifically designed* or modified for the articles in paragraphs (a) through (d) of this category, *except for such items as are in normal commercial use*." Emphasis added. However, the proposed Category XII does not fully employ this "specifically designed" distinction, focusing more on the limits of commercial performance rather than on defining the characteristics of military utility and significance.

The internationally-agreed Wassenaar Munitions List generally covers commodities and components not "specifically designed" for military purposes and, under the U.S. regulations, these items are identified on the Commerce Control List ("CCL"), which is part of the less restrictive Export Administration Regulations. LiDAR systems that are not "specifically designed" for military applications should be similarly treated.

The Coalition believe that the proposed Category XII revisions appear to be much broader than the current Category XII(b) controls. If adopted as proposed, it will stunt the growth of the rapidly advancing LiDAR technology for use in commercial small UAS operations, and will likely disincentivize investment by U.S. companies in the emerging technological markets for UAVs and UAS.

In addition to this general commentary, the UAV Coalition also provides the following comments on specific provisions:

Proposed ITAR control (b)(6)

The proposed Note to (b)(6) excludes LiDAR systems or equipment "for civil automotive applications having a range limited to 200 m or less." We believe this reflects the view that such applications are intended only for commercial and consumer use. The Coalition requests the Note include a similar exclusion for LiDAR systems and equipment for "commercial and consumer operations of a small unmanned aircraft system in Class G airspace having a range limited to 1,500 m or less." This range is needed to provide maximum protection against collision with structures or other aircraft.

Proposed ITAR control (b)(8)(ii)

This proposed subparagraph appears to cover small UAS operations with a LiDAR system that can identify a power line or wire at a certain distance. A dramatically beneficial use of small UAVs now and in the future will be to inspect power lines and cell towers. The FAA has granted many section 333 exemptions to allow inspection and monitoring of such energy and communications infrastructure. Thus, the Coalition requests that the note requested above for (b)(6) be included also as a note to (b)(8)(ii).

Proposed ITAR control (b)(8)(iii) and (iv)

It is uncertain whether these proposed provisions would apply to LiDAR systems as part of a small UAS operation for commercial or consumer use. If either would apply, for the reasons stated above the Coalition requests that a note be added to exclude "LiDAR systems and equipment for commercial and consumer operations of small UAS."

In summary, LiDAR systems and equipment for use with small unmanned aircraft systems are designed and intended for consumer and commercial use, in the United States and other countries, and thus should be excluded from the ITAR Munitions List.

Sincerely,

____

Gregory S. Walden
Tatman R. Savio
Rebekah Jones

Akin Gump Strauss Hauer & Feld LLP
1333 New Hampshire Avenue NW
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for the Small UAV Coalition

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Submission Via Email

July 06, 2015

Mr. C. Edward Peartree
Director, Office of Defense Trade Controls Policy
Directorate of Defense Trade Controls
U.S. Department of State

and

Mr. Dennis Krepp
Office of National Security and Technology Transfer Controls
Bureau of Industry and Security
U.S. Department of Commerce

Subject: JOINT Comments on the Proposed Rules Promulgated by the U.S. Departments of State and Commerce regarding the Amendment of Category XII of the International Traffic in Arms Regulations ("ITAR") United States Munitions List ("USML") and the Revision of the Export Administration Regulations ("EAR") to Control Items No Longer Warranting Control in Category XII of the USML per Export Control Reform

Dear Mr. Peartree and Mr. Krepp:

Sofradir EC, Inc., located at 373 US Hwy 46W, Fairfield, NJ 07004, hereby submits **joint comments** on:

- the Department of State Proposed Rule, 80 Fed. Reg. 25821, concerning Amendment of Category XII of the International Traffic in Arms Regulations' ("ITAR") United States Munitions List ("USML") and

- the Department of Commerce's Proposed Rule, 80 Fed Reg. 25798, concerning revision to the Export Administration Regulations ("EAR") to control various items no longer warranting control in Category XII of the USML per Export Control Reform.

Sofradir EC is submitting joint comments because these comments affect both sets of proposed rules in a common way, and Sofradir EC believes that it is a better use of resources to file a single set of comments on the proposed rules, rather than submitting two sets of comments saying the same things. Where comments are directed at language in one of the proposed rules versus the other proposed rule, yet both proposed rules address the same issue, these comments should be read as applying to both proposed rules.

We are concerned at the proposed changes in the regulations as it seems it will have a negative impact on most of the affected businesses. The proposed rewrite would result in:

1. an expansion of the products that are controlled for export under Category XII of the USML,
2. the significant expansion of licensing requirements under the EAR, and
3. "Presumption of denial" of export licenses involving any transfer of technology regarding EAR-controlled camera systems and sensor assemblies controlled under ECCNs 6A002 and 6A003.

The first and most significant impact is the new term that has been presented in the rewrite is **Permanently Encapsulated Sensor Assembly** ("PESA"). : We do not believe that the Department of State's and Commerce's proposal for the creation of a new standard for incorporating ITAR controlled IRPFAs and components in EAR-controlled sensor assemblies and cameras, under ECCNs 6A002 and 6A003 respectively, in "permanently encapsulated sensor assemblies" is a step forward. As we discuss in the next comment, perhaps if the term "permanently encapsulated sensor assembly" was defined better and more information was provided to indicate the level of "permanence" or the "manner of encapsulation of the sensor assembly" expected by the U.S. Government, we would be more supportive.

PESA seems to have been adopted without a clear explanation of what is meant by "permanently encapsulated" to prevent direct access to the IRFPA. For example, does this term apply only at the lowest chip level - the packaging of the raw detector in a vacuum sealed package? Or does it apply all the way through the building of a core/camera system for commercial applications?

It goes on to state disassembly of the sensor assembly and removal of the IRPFA without destruction or damage? Are there certain methods that are presumed acceptable or unacceptable? What is actually meant by removal without damage or destruction?

Will the government provide a better explanation as to what is meant by permanent and at the different levels of the product?

How does one incorporate an ITAR DEWAR, an ITAR detector, an ITAR cold finger, an ITAR cryocooler in a commercial product in such a way that each part is damaged or made inoperable if the foreign party attempts to remove any of the components?

If a system, cooled or uncooled has more than one ITAR component does each component need to be made inoperable, and how damaged do the parts have to be?

What happens to products that we have developed as commercial systems that have fallen under 6A002A and 6A003A with ITAR components embedded therein that are not considered PESA? Do they get transferred from the EAR to ITAR?

The term Permanent Encapsulated Sensor Assembly is filled with ambiguity and needs to be better defined so manufacturers have clear direction on how to proceed. Additional terms used in the two proposed rules need to be better defined. Terms that are unclear are:

- Multispectral IRFPA set forth in proposed USML Category XII(c)(6) at 80 Fed. Reg. 25826. It is not clear what a "multispectral IRFPA" is; does this term refer to IRFPAs that can operate in separate spectrum bands (e.g., IRFPAs that can operate in both MWIR and LWIR bands)?

- Active cold finger set forth in proposed USML Category XII(c)(9)(ii) at 80 Fed. Reg. 25826, what is an "active" cold finger? Is there a "passive" cold finger?

The second impact the rewrite is as it relates to the release of technology. The definition of "Technology" requires significant clarification to enable businesses to effectively plan and execute product plans and overall commerce. A strict reading of the proposed rules as they pertain to the release of lower level technology, controlled under 6E001 and 6E002 would result in a higher level of control for EAR technology than what applies for the ITAR technology permitted to be exported under TAAs. How does this fall in line with ECR, having higher controls for a lower controlled product?

We feel that the Department of State and Department of Commerce should work on presenting one cohesive document that presents clear definitions of new terms and provide specific guidelines and methodology to manufactures to achieve compliance to the regulations.

Regards,

Michelle Intiso
Export Compliance Manager
Sofradir EC Inc.

From:	Jennifer Douris
To:	DDTCPublicComments
Subject:	ITAR Amendment—Category XII
Date:	Monday, July 06, 2015 10:39:21 PM

Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

On behalf of SPIE, the international society for optics and photonics, we appreciate the opportunity to comment on the proposed changes to the USML. SPIE is the largest international not-for-profit society in optics, photonics and imaging. Together with our 18,000 individual members and 600 corporate members, the Society seeks to build a better world with light through scientific education and innovation.

[Please see the attached document "STATE" and supporting product information for a more detailed assessment of the provisions within the proposal. Due to size limitations, SPIE will submit multiple comments with the remaining supporting documentation. Attached files include A-M]

Photonics is an exciting growth area based on light. Photonic components (optics, sensors, fibers, lasers, photodetectors, light modulators, lasers, etc.) themselves make up a substantial global product market of more than $150 billion, with around 700,000 jobs. When basic photonic products are added (such as displays, the optical telecommunications hardware, equipment for precision production and metrology for manufacturing, solar energy converters, LED lighting, cameras and light based medical instruments) the product market is calculated at $500 billion with 2.2 million jobs worldwide. Photonics, as an enabling technology, underpins many trillions in the services of today's economy, including data, entertainment, and e-commerce. Advances in photonics are key to the future of consumer brand name companies such as Google, Facebook, as well as realizing solutions to familiar diseases.

SPIE supports an overhaul of U.S. export controls to save American jobs and better protect our most sensitive military items through the Export Control Reform (ECR) initiative that was launched in 2009. Current guidelines are vague, inconsistent and outdated. Overly restrictive regulation on dual-use technologies, and the inconsistent interpretation/ enforcement of regulations have created business, research, and workforce barriers that are limiting U.S. leadership in science and technology. Government export rules have driven high-tech jobs abroad and have made U.S. companies uncompetitive in the global marketplace. We are losing business to foreign companies that use "ITAR-free" as a marketing slogan. According to the White House, ECR was launched "with the goal of strengthening national security and the competitiveness of key U.S. manufacturing and technology sectors by focusing on current threats, as well as adapting to the changing economic and technological landscape. This review determined that the current export control system is overly complicated, contains too many redundancies, and, in trying to protect too much, diminishes our ability to focus our efforts on the most critical national security priorities." In an April 2010 speech regarding the ECR Initiative, Secretary Robert Gates stated that we need a system where "higher walls are placed around fewer, more critical items."

However, the proposal for Category XII deviates greatly from these core principles of the Export Control Reform (ECR) Initiative. The proposal for Category XII is far more complex and confusing than the current Category XII, and contains multiple redundancies. Instead of limiting the list to "fewer items", this proposal is actually expansive in the list of commodities it proposes to control. Spreading enforcement resources thin by trying to control too much, and not focusing on the most critical military technologies will ultimately hurt U.S. national security.

Furthermore, the proposal does not properly recognize the foreign availability of many of the commodities that it proposes to control. (See attached doc "STATE" and supporting documentation). Commercial markets dominate sales of many technologies described in the Category XII proposal. For example, there are at least 9 companies located in 7 countries outside the US, manufacturing uncooled infrared detectors. All of those countries control those items as commercial/dual-use.

It has been stated previously that there is a high rate of approval to companies that apply for licenses to the Department of State for USML controlled items. Therefore, the conclusion being, why is there really a problem with an item being listed on the USML, DoD just wants the chance to review the item before export. However the realities of the market place prevent many companies from even getting to the point of applying for an export license with the State Department. Reported approval times from companies vary, but we have been told they take generally around 2-3 months for an application. Why would a foreign client wait for a determination from the State Department when similar items are being sold without a license requirement, and arrive in a matter of days or weeks? For example:

- China, Pearmain 384x288, 50 Hz uncooled core, lead time 1 to 7 days. http://redirect.state.sbu/?url=http://pearmain.manufacturer.globalsources.com/si/6008813092486/pdtl/Thermal-imaging/1025737934/Thermal-Camera-Module.html

- China, Dali 384x288, 50 Hz uncooled core, lead time 2-4 weeks (200 units), http://redirect.state.sbu/?url=http://www.ir-thermalimagingcamera.com/sale-2713265-8-14um-ip54-industrial-thermal-imaging-module-for-security-surveillance.html

- Taiwan & Canada, Allied Scientific Pro either a 640x480 or a 384x288, 60 Hz uncooled core, lead time 2 weeks (up to 1000 units) http://redirect.state.sbu/?url=http://alliedscientificpro.com/shop/uncooled-lwir-infrared-sensor-8-to-14-microns/

The additional revenue gained by export sales to foreign markets, is revenue that can be reinvested back into companies, fueling rapid growth. Overtime this revenue loss has a great impact on companies prevented from competing in the global marketplace. Ultimately, this is likely to result in a reduction of the industrial base in the U.S., as seen in the commercial satellite industry. If the U.S military is forced to buy these items from foreign countries, this also becomes a national security issue.

Another issue repeated in this proposal is language stating that any products that result from developmental research funded by the Department of Defense would have a default designation of ITAR [Paragraph (b)(14); Paragraph (c)(21); Paragraph (d)(9)]. There is a note listing some exceptions to this language, including a DoD contract or other funding authorization stating that the developmental research is meant for Dual-use purposes, a commodity jurisdiction determining the item EAR, or if the product is in production. However, these exceptions are difficult to utilize. Obtaining dual-use language in a defense contract is no easy task. Companies often lack the leverage to request changes to contracts. This is especially true if a company is a subcontractor and the base contract has already been negotiated and closed. We have also been told that contracting officers are instructed to not make ITAR designations via the contract.

The other exception is if a company receives a commodity jurisdiction (CJ) designating the item to fall under EAR. However, no company will invest the time and money needed to develop a commercial application with the uncertainty of a CJ application, needed upon completion. Though every product developed in the U.S. could potentially be subject to a CJ application determination, the default designation as written in the proposal would make investment in commercial applications an impractical risk. Companies therefore would need to make the determination whether accepting DoD funding is worth forfeiting potential revenue from commercial applications. DoD developmental research funding is often pursued for the commercial potential of the underline technology, not for one or two items to be sold to the military. There is no guarantee that Defense funded research will lead to significant purchase of any product resulting from the research. Therefore forcing companies to draw this line regarding defense funded developmental research could mean that DoD will reduce the pool of companies willing to use their technological expertise to produce an item specifically for a military application.

An example of DoD funded developmental research that turned into the development of items with significant commercial application is the Quantum Cascade Laser (QCL). DoD has generally funded activities to advance certain wavelengths in QCLs. The underlying physics and the technology has now been applied across most wavelengths in the mid-IR, enabling the commercialization of the entire spectrum. As a result, hundreds of lasers have been sold into research institutions where advances are being made by scientist and Nobel prize winners around the world in areas of Life Sciences, Medical diagnostics, and Environmental studies. One of the systems based on this technology recently discovered a previously unknown subclass of renal carcinoma cell cancer by the NIH. The DoD funded this research without ITAR restrictions.

Another example of DoD funded developmental research is specialty laser fibers. Unlike QCL technology, industry has primarily funded the development of this technology. However, as part of a strategy to make the most of the return on investment, some defense funding was accepted via a subcontract to develop a specific defense application. Often companies who have spent considerable dollars on financing developmental research with commercial applicability in mind will also accept a small subcontract (less than 2% of overall investment in research funding) to develop a military application specifically for military purposes. Though it is possible that the commodity developed for military purposes ends with a lucrative defense contract to purchase the specific product, it is by no means a guaranty. Therefore, accepting a subcontract for a military application on privately funded research, such as specialty laser fibers, would no longer be worth the risk of classifying any item developing from the entire developmental research as ITAR.

The proposal for Category XII would also regulate companies to performance parameters that are either simply at the edge of today's commercial market or intruding on the commercial market, as opposed to defining parameters unique to military sensitive items (See Comments in Attached Doc "STATE"). This approach is troublesome considering the rapid movement of technology, contrasted with the extremely slow and difficult process of changing U.S. regulations.

Where appropriate military parameters cannot be found or agreed upon, the "specially designed" criteria (as defined in §120.41 of the USML) should be utilized to ensure that dual-use technologies do not fall under the USML. Another solution to limit an overly expansive Category XII USML is to align the list with the applicable internationally agreed upon Wassenaar Munitions List, to ensure equal footing with our allies. Based on the input received from impacted U.S. companies, it is SPIE's position that this proposal needs to be fundamentally rewritten in order to better align with commercial market realities and to follow the ECR principles that initiated this review.

Many of the companies that SPIE has spoken with also take issue with the EAR companion rule released by the Department of Commerce. For both proposed rules, companies have stated that they are so confusing the company is unlikely to comment because they cannot read it and ascertain the implications. What is clear from reviewing the EAR proposed rule is that many of the license exceptions are being removed and that worldwide Regional Stability Control is being imposed with a presumption of denial to many of the applicable ECCNs. The benefit of moving dual-use technologies over to the CCL is the flexibility this list can provide, especially when exporting to friendly countries. This benefit no longer exists if a company is required to get a license in order to sell to Canada. This level of control is not justified given the global commercial availability of many of these products, and stands to continue to put U.S. companies at a commercial disadvantage.

If you require any further information, please contact Jennifer Douris, SPIE Government Affairs Director, at 202-246-7348 or via email at Jenniferd@spie.org.

Sincerely,

Eugene Arthurs
CEO
SPIE, the international society for optics and photonics

[Billing Code 4710-25]

DEPARTMENT OF STATE

22 CFR Part 121

RIN 1400-AD32

[Public Notice:]

Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII.

AGENCY: Department of State.

ACTION: Proposed rule.

SUMMARY: As part of the President's Export Control Reform effort, the Department of State proposes to amend the International Traffic in Arms Regulations (ITAR) to revise Category XII (fire control, range finder, optical and guidance and control equipment) of the U.S. Munitions List (USML) to describe more precisely the articles warranting control on the USML. The revisions contained in this rule are part of the Department of State's retrospective plan under E.O. 13563 completed on August 17, 2011. The Department of State's full plan can be accessed at http://www.state.gov/documents/organization/181028.pdf.

DATES: The Department of State will accept comments on this proposed rule until [insert date 60 days from date of publication in the *Federal Register*].

ADDRESSES: Interested parties may submit comments within 60 days of the date of publication by one of the following methods:

- E-mail: *DDTCPublicComments@state.gov* with the subject line, "ITAR Amendment – Category XII."

Comment [1]: The proposed rule does not meet the goals of export control reform which is higher fences around fewer items. Rather it seeks to move items to the 600 series or remove license exceptions from commodities such as FPAs and impose license requirements to items being shipped to Canada. Furthermore, it seeks to roll back controls on linear arrays that had been licensable under Commerce. The carve out rule which allowed military image intensifier tubes and focal plane arrays when incorporated in to a civil product has been restricted further requiring parts to be unserviceable and thereby rolls back many items that were exportable through Commerce. The rule seeks to define ambiguously new terms such as core and permanently encapsulated without any thought about the implications of exporters who need to understand them not to mention why such terms are even needed. Furthermore, much of what is captured is produced and manufactured and controlled by non-US companies. This falls short of the "crown jewels" that Sec Gates referred to in his speech of 2010.

I would recommend a completely new approach to the USML proposed rule as well as the Commerce Companion rule for the following reasons:
1. The proposed language captures existing civilian items as well as future ones.
2. Parts of the proposed language are ambiguous and would lead to additional commodity jurisdiction filings.
3. The proposed language does not meet the objectives of ECR which is higher fences around fewer items.
4. The proposed language recaptures items previously determined to be subject to the EAR since the carveout language has been weakened as well as ignoring on CCL which has ECCN of 6A002.a.3.d to identify linear focal plane arrays which are listed in this draft.
5. The proposed language does not provide any military parameters rather it relies on dual-use parameters like detector count and wavelength.
6. The 120+ page companion rule is too complex. It appears to remove important license exceptions and destinations as well as create new ECCNs that would require me to hire additional staff to review and keep up the language which would dissuade me from wanting to seek exports for my products.

I would suggest that if another attempt is made at revising the language, that it should start with taking the existing language in Cat 12 and replace specifically with "specially designed". Therefore the use of specially designed is the only way to draw a clear line. If the military is the only customer for an item it should be on the USML, if there is a civil market it should be considered a dual use item in order to keep US industry at the fore front of innovation. To do otherwise will allow foreign manufacturers to continue to use No ITAR controls as a way to innovate and buy US companies. Ultimately the US warfighter could be buying more capable systems from foreign sources as it does now (KC tanker program and clip-on weapon sight program).

- Internet: At *www.regulations.gov,* search for this notice by using this rule's RIN (1400-AD32).

Comments received after that date will be considered if feasible, but consideration cannot be assured. Those submitting comments should not include any personally identifying information they do not desire to be made public or any information for which a claim of confidentiality is asserted. All comments and transmittal e-mails will be made available for public inspection and copying after the close of the comment period via the Directorate of Defense Trade Controls website at *www.pmddtc.state.gov*. Parties who wish to comment anonymously may do so by submitting their comments via *www.regulations.gov*, leaving the fields that would identify the commenter blank and including no identifying information in the comment itself. Comments submitted via *www.regulations.gov* are immediately available for public inspection.

FOR FURTHER INFORMATION CONTACT: Mr. C. Edward Peartree, Director, Office of Defense Trade Controls Policy, Department of State, telephone (202) 663-2792; e-mail *DDTCPublicComments@state.gov*. ATTN: Regulatory Change, USML Category XII.

SUPPLEMENTARY INFORMATION: The Directorate of Defense Trade Controls (DDTC), U.S. Department of State, administers the International Traffic in Arms Regulations (ITAR) (22 CFR parts 120-130). The items subject to the jurisdiction of the ITAR, *i.e.*, "defense articles," are identified on the ITAR's U.S. Munitions List (USML) (22 CFR 121.1). With few exceptions, items not subject to the export control jurisdiction of the ITAR are subject to the jurisdiction of the Export Administration Regulations ("EAR," 15 CFR parts 730-774, which includes the Commerce Control List (CCL) in Supplement No. 1 to Part 774), administered by the

Bureau of Industry and Security (BIS), U.S. Department of Commerce. Both the ITAR and the EAR impose license requirements on exports and reexports. Items not subject to the ITAR or to the exclusive licensing jurisdiction of any other set of regulations are subject to the EAR.

Revision of Category XII

This proposed rule revises USML Category XII, covering fire control, range finder, optical and guidance and control equipment, to advance the national security objectives set forth above and to more accurately describe the articles within the category, in order to establish a "bright line" between the USML and the CCL for the control of these articles.

Paragraph (a) is revised to add subparagraphs (1) through (9) to more clearly describe the articles controlled in (a).

Paragraph (a)(1) is added for fire control systems and equipment.

Paragraph (a)(2) is added for weapons sights and weapons aiming or imaging systems, with certain infrared focal plane arrays, image intensifier tubes, ballistic computers, or lasers.

Paragraph (a)(3) is added for electronic or optical weapon positioning, laying, or spotting systems or equipment.

Paragraph (a)(4) is added for certain laser spot trackers and laser spot detectors.

Paragraph (a)(5) is added for bomb sights and bombing computers.

Paragraph (a)(6) is added for electro-optical missile or ordnance tracking or guidance systems.

Paragraph (a)(7) is added for electro-optical systems or equipment that automatically detect and locate weapons launch or fire.

Paragraph (a)(8) is added for certain remote wind sensing systems or equipment for enhanced targeting.

Paragraph (a)(9) is added for certain helmet mounted display (HMD) systems.

Paragraph (b) is revised to add subparagraphs (1) through (14) to more clearly describe the articles controlled in (b).

Paragraph (b)(1) is added for laser target designators or coded target markers.

Paragraph (b)(2) is added for certain infrared laser aiming or target illumination systems.

Paragraph (b)(3) is added for certain laser range finders.

Paragraph (b)(4) is added for certain targeting or target location systems.

Paragraph (b)(5) is added for optical augmentation systems.

Paragraph (b)(6) is added for certain light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems and includes a carve out for certain LIDAR systems for civil automotive applications.

Paragraph (b)(7) is added for certain synthetic aperture LIDAR or LADAR systems.

Paragraph (b)(8) is added for LIDAR, LADAR, or other laser range-gated identified in subparagraphs (i) – (vi).

Paragraph (b)(9) is added for certain lasers for electronic combat systems controlled in Category XI(a)(4).

Paragraph (b)(10) is added for certain tunable semiconductor lasers.

Paragraph (b)(11) is added for certain non-tunable single transverse mode semiconductor lasers.

Paragraph (b)(12) is added for certain non-tunable multiple transverse mode semiconductor lasers.

Paragraph (b)(13) is added for laser stacked arrays identified in subparagraphs (i) – (iv).

Paragraph (b)(14) is added for developmental lasers funded by the Department of Defense.

Paragraph (c) is revised to add subparagraphs (1) through (21) to more clearly describe the articles controlled in (c).

Paragraph (c)(1) is added for certain second and third generations image intensifier tubes (IITs).

Paragraph (c)(2) is added for certain photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs).

Paragraph (c)(3) is added for certain one-dimensional photon detector IRFPAs in a permanent encapsulated sensor assembly.

Paragraph (c)(4) is added for certain two-dimensional photon detector IRFPAs in a permanent encapsulated sensor assembly.

Paragraph (c)(5) is added for certain microbolometer IRFPAs in a permanent encapsulated sensor assembly.

Paragraph (c)(6) is added for multispectral IRFPAs in a permanent encapsulated sensor assembly.

Paragraph (c)(7) is added for certain charge multiplication focal plane arrays.

Paragraph (c)(8) is added for certain charge multiplication focal plane arrays in a permanent encapsulated sensor assembly.

Paragraph (c)(9) is added for certain integrated IRFPA dewar cooler assemblies (IDCAs).

Paragraph (c)(10) is added for gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 200 microradians.

Paragraph (c)(11) is added for gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 100 microradians.

Paragraph (c)(12) is added for infrared imaging camera cores identified in subparagraphs (i) – (xi). Camera cores meeting the shock tolerance criteria described in (c)(12)(ii) are controlled on the USML whether or not they are tested to meet these criteria.

Paragraph (c)(13) is added for binoculars, biocular, monoculars, goggles, or head- or helmet-mounted imaging systems with IITs or camera cores controlled in this category.

Paragraph (c)(14) is added for certain targeting systems.

Paragraph (c)(15) is added for infrared search and track (IRST) systems.

Paragraph (c)(16) is added for infrared imaging systems identified in subparagraphs (i) – (ix).

Paragraph (c)(17) is added for certain terahertz imaging systems.

Paragraph (c)(18) is added for near-to-eye display systems or equipment, specially designed for articles controlled in this subchapter.

Paragraph (c)(19) is added for systems or equipment that project radiometrically calibrated scenes directly into the entrance aperture of an electro-optical or infrared (EO/IR) sensor controlled in this subchapter within either the spectral band exceeding 10 nm but not exceeding 400 nm, or the spectral band exceeding 900 nm but not exceeding 30,000 nm.

Paragraph (c)(20) is added for certain systems or equipment incorporating an infrared beacon or emitter specially designed for Identification Friend or Foe (IFF) and specially designed parts and components therefor.

Paragraph (c)(21) is added for developmental imaging systems funded by the Department of Defense.

A note is added to paragraph (c) to address the incorporation of these defense articles into commercial items. With minor exceptions, all bare IRFPAs are controlled in Category XII, paragraph (c)(2). However, once an IRFPA has been incorporated into a permanent encapsulated sensor assembly, it ceases to be controlled in paragraph (c)(2) because it is incorporated into a higher order assembly. The permanent encapsulated sensor assembly will be controlled in paragraphs (c)(3) – (6), if it meets the control parameters of one of those paragraphs. These control parameters are set at a level that the Department has determined excludes most commercial products. Further, once most IRFPAs and permanent encapsulated sensor assemblies are incorporated into a camera core, monocular, or binocular or other higher order system, that system will not be subject to the ITAR or require authorization from the Department for export, unless it is specifically enumerated. Most multi-spectral IRFPAs and IRFPAs with charge multiplication are excluded from the note and remain subject to the ITAR, even when incorporated into higher order assemblies or end-items. IRFPA, permanent encapsulated sensor assemblies, camera cores, monoculars, binoculars, and other higher order systems not enumerated on the USML are generally subject to the EAR.

Paragraph (d) is revised to move controls on Global Navigation Satellite System (GNSS) equipment from Category XV and to add subparagraphs (1) through (9) to more clearly describe the articles controlled in (d).

Paragraph (d)(1) is added for certain guidance or navigation systems.

Paragraph (d)(2) is added for certain accelerometers.

Paragraph (d)(3) is added for certain gyroscopes or angular rate sensors.

Paragraph (d)(4) is added for certain mobile relative gravimeters.

Paragraph (d)(5) is added for certain mobile gravity gradiometers.

Paragraph (d)(6) is added for Global Navigation Satellite System receiving equipment from Category XV.

Paragraph (d)(7) is added for certain GNSS anti-jam systems employing adaptive antennas.

Paragraph (d)(8) is added for certain GNSS security devices.

Paragraph (d)(9) is added for developmental guidance, navigation, or control devices, systems or equipment funded by the Department of Defense.

Paragraph (e) is revised to add subparagraphs (1) through (15) to more clearly describe the parts and components controlled in (e).

A significant aspect of this more positive, but not yet tiered, proposed USML category is that it does not contain controls on all generic parts, components, accessories, and attachments that are specifically designed or modified for a defense article, regardless of their significance to maintaining a military advantage for the United States. Rather, it contains, with a few exceptions, a positive list of specific types of parts, components, accessories, and attachments that continue to warrant control on the USML. The exceptions pertain to those parts, components, accessories, and attachments identified as “specially designed.”

Paragraph (e)(1) is added for specially designed optical sensors for electronic combat systems controlled in Category XI(a)(4).

Paragraph (e)(2) is added for certain image intensifier tube (IIT) parts and components identified in subparagraphs (i) – (vii).

Paragraph (e)(3) is added for certain wafers incorporating structures for Read-Out Integrated Circuits (ROICs) controlled in (e)(4) or (e)(5) or for IRFPA detectors controlled in (c)(2).

Paragraph (e)(4)is added for ROICs specially designed for IRFPAs.

Paragraph (e)(5) is added for certain ROICs specially designed for a system, camera core, or packaged IRFPA controlled in paragraph (c).

Paragraph (e)(6) is added for specially designed vacuum packages or other sealed enclosures for an IRFPA or IIT controlled in paragraph (c).

Paragraph (e)(7) is added for integrated IRFPA dewar cooler assembly (IDCA) parts and components identified in subparagraphs (i) – (iv).

Paragraph (e)(8) is added for specially designed IRFPA Joule-Thomson (JT) self-regulating cryostats.

Paragraph (e)(9) is added for specially designed infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings.

Paragraph (e)(10) is added for specially designed drive, control, signal or image processing electronics.

Paragraph (e)(11) is added for signal processing electronics identified in subparagraphs (i) – (iii).

Paragraph (e)(12) is added for specially designed near-to-eye displays.

Paragraph (e)(13) is added for specially designed resonators, receivers, transmitters, modulators, gain media, and drive electronics or frequency converters.

Paragraph (e)(14) is added for two-dimensional infrared scene projector emitter arrays (i.e., resistive arrays) that emit infrared radiation within the 900 nm to 30,000 nm wavelength range.

Paragraph (e)(15) is added for classified parts, components, accessories, attachments, and associated equipment.

A note is added to paragraph (e) to address the incorporation of these defense articles into commercial items.

Paragraph (f) is revised to more clearly describe the technical data and defense services controlled in paragraph (f).

Three notes are added to paragraph (f) to address technical data and defense services when incorporating defense articles into commercial items. Note 1 clarifies that technical data directly related to IITs, IRFPAs, integrated IRFPA dewar cooler assemblies and related wafers and ROICs controlled in this Category remains USML controlled, even when those defense articles are part of a system that is subject to the EAR. Note 2 enumerates certain technical data and software that are directly related to the defense articles controlled in this Category in paragraphs A, B, and C. It also includes a note to paragraph A, identifying certain technology that is not technical data. Note 3 states that certain technology for the incorporation or integration of IRFPAs and IITs in to items subject to the EAR, including into permanent encapsulated sensor assemblies, is subject to the EAR.

A new (x) paragraph has been added to USML Category XII, allowing ITAR licensing for commodities, software, and technology subject to the EAR provided those commodities, software, and technology are to be used in or with defense articles controlled in USML Category XII *and* are described in the purchase documentation submitted with the application.

Finally, articles common to the Missile Technology Control Regime (MTCR) Annex and the USML are to be identified on the USML with the parenthetical “(MT)” at the end of each section containing such articles. A separate proposed rule will address the sections in the ITAR that include MTCR definitions.

The following definitions explain and amplify terms used in this Category and are provided to assist exporters in understanding the scope of the proposed control.

Charge multiplication is a form of electronic image amplification, the generation of charge carriers as a result of an impact ionization gain process.

Focal plane array is a linear or two-dimensional planar layer, or combination of planar layers, of individual detector elements, with or without readout electronics, which work in the focal plane.

Note: This definition does not include a stack of single detector elements or any two, three, or four element detectors provided time delay and integration is not performed within the element.

Image intensifier tube refers to an imaging device that incorporates a photoemissive transducer (i.e., photocathode) and achieves electron image amplification in the vacuum space.

Microbolometer is a thermal imaging detector that, as a result of a temperature change in the detector caused by the absorption of infrared radiation, is used to generate a usable signal.

Multispectral refers to producing discrete outputs associated with more than one spectral band of response.

Request for Comments

As the U.S. Government works through the proposed revisions to the USML, some control parameters are proposed recognizing that they will control items in normal commercial use and on the Wassenaar Arrangement's Dual Use List. With the thought that multiple perspectives would be beneficial to the USML revision process, the Department welcomes the assistance of users of the lists and requests input on the following:

1) A key goal of this rulemaking is to ensure the USML and the CCL together control all the items that meet Wassenaar Arrangement commitments embodied in Munitions List Categories 5, 11 and 15 (WA-ML15) and the relevant Dual Use List Categories including the IRFPAs in Category 6 (WA-DU 6.A.2). To that end, the public is asked to identify any potential lack of coverage brought about by the proposed rules for Category XII contained in this notice and the new and revised ECCNs published separately by the Department of Commerce when reviewed together.

2) Another key goal of this rulemaking is to identify items proposed for control on the USML or the CCL that are not controlled on the Wassenaar Arrangement's Munitions or Dual Use List. The public is asked to identify any items proposed for control on the USML that are not controlled on the Wassenaar Arrangement's Munitions or Dual Use List.

3) A third key goal of this rulemaking is to establish a "bright line" between the USML and the CCL for the control of these materials. The public is asked to provide specific examples of control criteria that do not clearly describe items that would be defense articles and thus do not establish a "bright line" between the USML and the CCL.

4) Although the proposed revisions to the USML do not preclude the possibility that items in normal commercial use would or should be ITAR-controlled because, *e.g.*, they provide the United States with a critical military or intelligence advantage, the U.S. government does not want to inadvertently control items on the ITAR that are in normal commercial use. Items that would be controlled on the USML in this proposed rule have been identified as possessing parameters or characteristics that provide a critical

military or intelligence advantage. The public is thus asked to provide specific examples of items, if any, that would be controlled by the revised USML Category XII that are now in normal commercial use. The examples should demonstrate actual commercial use, not just potential or theoretical use, with supporting documents, as well as foreign availability of such items.

5) For any criteria the public believes control items in normal commercial use, the public is asked to identify parameters or characteristics that cover items exclusively or primarily in military use.

6) For any criteria the public believes control items in normal commercial use, the public is asked to identify the multilateral controls (such as the Wassenaar Arrangement's Dual Use List), if any, for such items, and the consequences of such items being controlled on the USML.

7) DDTC seeks public comments on each paragraph of the proposed USML Category XII. In addition, DDTC specifically seeks public comments on the following concepts that are introduced in proposed USML Category XII: A) using integration of an IRFPA into a permanent encapsulated sensor assembly as a control parameter; B) using the incorporation of an IRFPA into an infrared imaging camera core as a control parameter and the definition of camera cores in the note to XII(c)(12); C) the weapon shock load control criterion in XII(c)(12)(ii); and D) proposed controls on specific technical data in XII(f).

REGULATORY ANALYSIS AND NOTICES

Administrative Procedure Act

The Department of State is of the opinion that controlling the import and export of defense articles and services is a foreign affairs function of the United States Government and that rules implementing this function are exempt from sections 553 (rulemaking) and 554 (adjudications) of the

Administrative Procedure Act (APA). Although the Department is of the opinion that this rule is exempt from the rulemaking provisions of the APA, the Department is publishing this rule with a 60-day provision for public comment and without prejudice to its determination that controlling the import and export of defense services is a foreign affairs function.

Regulatory Flexibility Act

Since this rule is exempt from the rulemaking provisions of 5 U.S.C. 553, it does not require analysis under the Regulatory Flexibility Act.

Unfunded Mandates Reform Act of 1995

This proposed amendment does not involve a mandate that will result in the expenditure by State, local, and tribal governments, in the aggregate, or by the private sector, of $100 million or more in any year and it will not significantly or uniquely affect small governments. Therefore, no actions were deemed necessary under the provisions of the Unfunded Mandates Reform Act of 1995.

Small Business Regulatory Enforcement Fairness Act of 1996

This proposed amendment has been found not to be a major rule within the meaning of the Small Business Regulatory Enforcement Fairness Act of 1996.

Executive Orders 12372 and 13132

This proposed amendment will not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 13132, it is determined that this proposed amendment does not have sufficient federalism implications to require consultations or warrant the preparation of a federalism summary impact statement. The regulations implementing

Executive Order 12372 regarding intergovernmental consultation on Federal programs and activities do not apply to this proposed amendment.

Executive Orders 12866 and 13563

Executive Orders 13563 and 12866 direct agencies to assess costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributed impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility. This rule has been designated a "significant regulatory action," although not economically significant, under section 3(f) of Executive Order 12866. Accordingly, the rule has been reviewed by the Office of Management and Budget (OMB).

Executive Order 12988

The Department of State has reviewed the proposed amendment in light of Executive Order 12988 to eliminate ambiguity, minimize litigation, establish clear legal standards, and reduce burden.

Executive Order 13175

The Department of State has determined that this rulemaking will not have tribal implications, will not impose substantial direct compliance costs on Indian tribal governments, and will not preempt tribal law. Accordingly, Executive Order 13175 does not apply to this rulemaking.

Paperwork Reduction Act

Following is a listing of approved Department of State collections that will be affected by revision of the U.S. Munitions List (USML) and the Commerce Control List pursuant to the President's Export Control Reform (ECR) initiative. The list of collections and the description of the manner in which they will be affected pertains to revision of the USML in its entirety, not only to the categories published in this rule. In accordance with the Paperwork Reduction Act, the Department of State will request comment on these collections from all interested persons at the appropriate time. In particular, the Department will seek comment on changes to licensing burden based on implementation of regulatory changes pursuant to ECR, and on projected changes based on continued implementation of regulatory changes pursuant to ECR. The information collections are as follows:

1) Statement of Registration, DS-2032, OMB No. 1405-0002. The Department estimates that between 3,000 and 5,000 of the currently-registered persons will not need to maintain registration following full revision of the USML. This would result in a burden reduction of between 6,000 and 10,000 hours annually, based on a revised time burden of two hours to complete a Statement of Registration.

2) Application/License for Permanent Export of Unclassified Defense Articles and Related Unclassified Technical Data, DSP-5, OMB No. 1405-0003. The Department estimates that there will be 35,000 fewer DSP-5 submissions annually following full revision of the USML. This would result in a burden reduction of 35,000 hours annually.

3) Application/License for Temporary Import of Unclassified Defense Articles, DSP-61, OMB No. 1405-0013. The Department estimates that there will be 200 fewer DSP-61 submissions annually following full revision of the USML. This would result in a burden reduction of 100 hours annually.

4) Application/License for Temporary Export of Unclassified Defense Articles, DSP-73, OMB No. 1405-0023. The Department estimates that there will be 800 fewer DSP-73 submissions annually following full revision of the USML. This would result in a burden reduction of 800 hours annually.

5) Application for Amendment to License for Export or Import of Classified or Unclassified Defense Articles and Related Technical Data, DSP-6, -62, -74, -119, OMB No. 1405-0092. The Department estimates that there will be 2,000 fewer amendment submissions annually following full revision of the USML. This would result in a burden reduction of 1,000 hours annually.

6) Request for Approval of Manufacturing License Agreements, Technical Assistance Agreements, and Other Agreements, DSP-5, OMB No. 1405-0093. The Department estimates that there will be 1,000 fewer agreement submissions annually following full revision of the USML. This would result in a burden reduction of 2,000 hours annually.

7) Maintenance of Records by Registrants, OMB No. 1405-0111. The requirement to actively maintain records pursuant to provisions of the ITAR will decline commensurate with the drop in the number of persons who will be required to register with the Department pursuant to the ITAR. As stated above, the Department estimates that up to 5,000 of the currently-registered persons will not need to maintain registration following full revision of the USML. This would result in a burden reduction of 100,000 hours annually. However, the ITAR does provide for the maintenance of records for a period of five years. Therefore, persons newly relieved of the requirement to register with the Department may still be required to maintain records.

List of Subjects in Part 121

Arms and munitions, Exports

Accordingly, for the reasons set forth above, Title 22, Chapter I, Subchapter M, part 121 is proposed to be amended as follows:

PART 121 – THE UNITED STATES MUNITIONS LIST

1. The authority citation for part 121 continues to read as follows:

Authority: Secs. 2, 38, and 71, Pub. L. 90–629, 90 Stat. 744 (22 U.S.C. 2752, 2778, 2797); 22 U.S.C. 2651a; Pub. L. 105–261, 112 Stat. 1920; Section 1261, Pub. L. 112-239; E.O. 13637, 78 FR 16129.

2. Section 121.1 is amended by reserving paragraph (e) in U.S. Munitions List Category VIII.

3. Section 121.1 is amended by revising U.S. Munitions List Category XII to read as follows:

§121.1 The United States Munitions List.

* * * * *

Category XII — Fire Control, Range Finder, Optical and Guidance and Control Equipment

*(a) Fire control, weapons sights, aiming, and imaging systems and equipment, as follows:

(1) Fire control systems or equipment, and specially designed parts and components therefor;

(2) Weapon sights, weapon aiming systems or equipment, and weapon imaging systems or equipment (e.g., clip-on), with or without an integrated viewer, display, or reticle, and incorporating or specially designed to incorporate any of the following:

Comment [2]: Insert specially designed due to lack of military parameters to identify civilian systems used in varmit hunting for farmers and cattle ranchers or law enforcement entities. Sagem is supplying US military with clip-on devices. See attachment Maxtech1. Foreign availability of items treated as dual use - See attachments: TWS-3100, PL76416

(i) An infrared focal plane array having a peak response at a wavelength exceeding 1,000 nm;

(ii) An article subject to this subchapter; or

(iii) A ballistic computer for adjusting the aim point display;

(3) Electronic or optical weapon positioning, laying, or spotting systems or equipment;

(4) Laser spot trackers or laser spot detection, location or imaging systems or equipment, with an operational wavelength shorter than 400 nm or longer than 710 nm, and a detection range greater than 300 m;

Note to paragraph (a)(4): For controls on LIDAR, see paragraph (b)(9) of this category.

(5) Bomb sights or bombing computers;

(6) Electro-optical missile or ordnance tracking systems or equipment, or electro-optical ordnance guidance systems or equipment;

(7) Electro-optical systems or equipment that automatically detect and locate weapons launch or fire;

(8) Remote wind-sensing systems or equipment specially designed for ballistic-corrected aiming, and specially designed parts and components therefor;

(9) Helmet mounted display (HMD) systems or equipment, incorporating optical sights or slewing devices, which include the ability to aim, launch, track, or manage munitions, or control infrared imaging systems or equipment, other than such items controlled in Category VIII, (e.g., Combat Vehicle Crew HMD, Mounted Warrior HMD, Integrated Helmet Assembly Subsystem, Drivers Head Tracked Vision System).

*(b) Lasers, and laser systems and equipment, as follows:

(1) Laser target designators or coded target markers;

(2) Aiming or target illumination systems or equipment having a laser output wavelength exceeding 710 nm;

(3) Laser rangefinders having any of the following:

(i) Q-switched laser pulse; or

(ii) Laser output wavelength exceeding 1,000 nm;

Comment [JD3]: Q-switch lasers have several civilian applications and therefore is not an appropriate parameter for defining a military item. For example: ophthalmic surgery http://goochandhousego.com/product-categories/lithium-niobate-q-switches/

(4) Targeting or target location systems or equipment incorporating or specially designed to incorporate a laser rangefinder controlled in paragraph (b)(3) of this category, and incorporating or specially designed to incorporate a Global Navigation Satellite System (GNSS), guidance or navigation article controlled in paragraph (d) of this category (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km range);

(5) Systems or equipment that use laser energy with an output wavelength exceeding 710 nm to exploit differential target-background retroreflectance in order to detect personnel or optical / electro-optical equipment (e.g., optical augmentation systems);

(6) Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);

Note to paragraph (b)(6): This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less.

(7) Synthetic aperture LIDAR or LADAR systems or equipment, having a stand-off range of 100 m or greater (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);

(8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or

Comment [4]: Insert specially designed due to lack of military parameters. Captures civilian LADAR systems.

Comment [5]: BOSCH makes systems for automotive applications that exceed this limit. See attachment BOSCH. 200 m seems arbitrary given that the BOSCH system detects at farther range.

Comment [6]: Insert specially designed due to lack of military parameters. 100 m seems to overlap with (6) above.

Comment [7]: Insert Specially designed due to lack of military parameters. Capture civil systems and overlap with (6) and (7). See attachments Vision Map_A3; Optech_CS-15000 Digital Camera; Microsoft_UltraCAM, Leica_ ADS80, KSI_OSDCAM, Intergraph_DMCII250 unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):

(i) Systems or equipment having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft, and incorporating or specially designed to incorporate a gimbal-mounted transmitter or beam director, and specially designed parts and components therefor;

(ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);

(iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geiger-mode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements;

(iv) Systems or equipment employing coherent heterodyne or coherent homodyne detection techniques, having an angular resolution of less (better) than 100 microradians and an operational carrier noise ratio (CNR) less than 10;

(v) Systems or equipment that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs); or

(vi) Systems or equipment specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;

(9) Lasers operating at a wavelength exceeding 3,000 nm that provide a modulated output for systems or equipment controlled in Category XI(a)(4);

(10) Tunable semiconductor lasers having an output wavelength exceeding 1,400 nm and an output power greater than 1 W;

(11) Non-tunable single transverse mode semiconductor lasers having an output wavelength exceeding 1,510 nm and either an average output power or continuous wave (CW) output power greater than 2 W;

(12) Non-tunable multiple transverse mode semiconductor lasers having an output wavelength exceeding 1,900 nm and either an average output power or CW output power greater than 2 W;

(13) Laser stacked arrays as follows:

Comment [JD8]: Laser stacked arrays are undefined

(i) Having an output wavelength not exceeding 1,400 nm and a peak pulsed power density greater than 3,300 W/cm^2;

(ii) Having an output wavelength exceeding 1,400 nm but less than 1,900 nm and a peak pulsed power density greater than 700 W/cm^2;

(iii) Having an output wavelength exceeding 1,900 nm and a peak pulsed power density greater than 70 W/cm^2; or

(iv) Having an output wavelength exceeding 1,900 nm, and either an average output power or CW output power greater than 20W;

(14) Developmental lasers and laser systems or equipment funded by the Department of Defense;

Comment [9]: See comments in base comment letter regarding "developmental" language;

Note 1 to paragraph (b)(14): This paragraph does not control developmental lasers and laser systems or equipment (a) in production, (b) determined to be subject to the EAR via a commodity jurisdiction determination (see § 120.4 of this subchapter), or (c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications.

Note 2 to paragraph (b)(14): Note 1 does not apply to defense articles enumerated on the U.S. Munitions List, whether in production or development.

Note 3 to paragraph (b)(14): This provision is applicable to those contracts or other funding authorizations that are dated XXXX, 2016, or later.

Note to paragraphs (b)(4) and (b)(6) - (8): "Payload" is the total mass that can be carried or delivered by the specified rocket, missile, SLV, drone or unmanned aerial vehicle that is not used to maintain flight. For definition of "range" as it pertains to rocket systems, see note 1 to paragraph (a) of USML Category IV. For definition of "range" as it pertains to aircraft systems, see note to paragraph (a) of USML Category VIII.

*(c) Infrared focal plane arrays, image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories, including cameras and cores, as follows:

(1) Image intensifier tubes (IITs) having a peak response within the wavelength range exceeding 400 nm but not exceeding 2,050 nm and incorporating either a microchannel plate described in paragraph (e)(2)(i) or electron sensing device described in paragraph (e)(2)(iv), as follows, and specially designed parts and components therefor:

Comment [10]: Insert specially designed as there is a lack of military parameters. The parameters provided are general (wavelength) and parameters are too low (500 microamps per lumen)

(i) Incorporating a multialkali photocathode having a luminous sensitivity exceeding 500 microamps per lumen (e.g., GEN 2 IITs);

Comment [11]: Generation 2 image intensifier tubes are produced only outside of the US and used in civil applications. See attachment XD4_a , russian I2 tube, Russian i2

(ii) Incorporating a compound semiconductor photocathode having a radiant sensitivity exceeding 20 mA/W (e.g., GEN 3 IITs);

(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;

Comment [12]: Insert specially designed as there is a lack of military parameters. Are items captured in c(3) caught here as well?. What is the necessity of parsing FPAs using permanent. Other countries make all of these FPAs and do not add this burden. Permanent is subject to interpretation and could cause Commodity Jurisdiction submissions as a manufacturer may know how to remove a component while a user may not.

Note 1 to paragraph (c)(2): This paragraph does not control lead sulfide or lead selenide IRFPAs having a peak response within the wavelength range exceeding 1,000 nm but not exceeding 5,000 nm and not exceeding 16 detector elements, or pyrolectric IRFPAs with detectors composed of any of the following or their variants: triglycine sulphate, lead-lanthanum-zirconium titanate, lithium tantalite, polyvinylidene fluoride, or strontium barium niobate.

Note 2 to paragraph (c)(2): For controls on readout integrated circuits (ROICs), see paragraphs (e)(4) and (e)(5).

(3) One-dimensional photon detector IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, having greater than 640 detector elements;

(4) Two-dimensional photon detector IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, having greater than 256 detector elements;

(5) Microbolometer IRFPAs described in paragraph (c)(2) in a permanent encapsulated sensor assembly, having greater than 328,000 detector elements;

(6) Multispectral IRFPAs in a permanent encapsulated sensor assembly, having a peak response in any spectral band within the wavelength range exceeding 1,500 nm but not exceeding 30,000 nm;

(7) Charge multiplication focal plane arrays having greater than 1,600 elements in any dimension and having a maximum radiant sensitivity exceeding 50 mA/W for any wavelength exceeding 760 nm but not exceeding 900 nm, and avalanche detector elements therefor;

(8) Charge multiplication focal plane arrays described in paragraph (c)(7) in a permanent encapsulated sensor assembly, and avalanche detector elements therefor;

Comment [13]: Roll back of existing CCL language (6A002.a.3.d.2.1) which states that linear arrays with a rectangular aspect ratio are not controlled.

Comment [14]: Insert specially designed due to lack of military parameters. Captures civil products in production. See attachment Hamamatsu Sensor and Camera_a; XENICS_a

Comment [15]: Insert specially designed due to lack of military parameters and low value (256). Captures civil items in production. See attachment XENICS_b; Cardinal 640; wdr

Comment [16]: Insert specially designed due to lack of military parameters and low value (328,000) which moves rapidly in the commercial market. Captures items in commercial production. See attachment sULIS_a; Bird-XGA

Comment [17]: Insert specially designed due to lack of military parameters.

Comment [18]: Insert specially designed due to lack of military parameters and low value. Does this meet the parameters – why should any EMCCD be USML since e2v is in UK and treats as a dual use item. Captures items in commercial production. See EMCCD_Synapse_01

Comment [19]: Insert specially designed due to lack of military parameters.

(9) Integrated IRFPA dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

(ii) Active cold fingers;

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category;

(10) Gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 200 microradians, and specially designed for articles controlled in this subchapter;

(11) Gimbals with two or more axes of active stabilization having a minimum root-mean-square (RMS) stabilization better (less) than 100 microradians;

<u>Note to paragraph (c)(11)</u>: This paragraph does not control gimbals containing only a non-removable camera payload operating exclusively in the visible spectrum (i.e., 400 nm to 760 nm).

(12) Infrared imaging camera cores (e.g., modules, engines, kits), and specially designed electronics and optics therefor, having any of the following:

(i) An image intensifier tube described in paragraph (c)(1);

(ii) Output imagery when subject to more than 20 weapon shock load events of 325 g for 0.4 ms and a microbolometer IRFPA having greater than 111,000 detector elements;

Comment [20]: Insert specially designed due to lack of military parameters. Captures items in commercial production. See attachments SELEX2, Blackbird

Comment [21]: Foreign availability of much higher performance and treated as dual use: See attachment AIM_SX095, Tehnika

Comment [22]: Insert specially designed due to a lack of military parameters. Seems to overlap with C(11).

Comment [23]: Insert specially designed due to lack of military parameters. Captures items in normal commercial use. See attachments: uavvision, xenicsgimbal
Don't think it is necessary to identify 2 different gimbal controls.

Comment [24]: Insert specially designed due to lack of military parameters. Captures items in normal commercial use described in subparagraph comments.

Comment [25]: 20 weapon shock load events are not tested for commercial products and are not found on spec sheets. Creates unlevel playing field for US manufacturers. See XENICS LWIR_modules_a does this meet this parameter ? Confusing. Why is shock not associated with non-microbolometer IRFPA modules or I2 tube modules ?; See attachment GWIR UFPAs

(iii) A microbolometer IRFPA described in paragraph (c)(2) having greater than 328,000 detector elements, or a microbolometer IRFPA described in paragraph (c)(5);

(iv) An IDCA described in paragraph (c)(9), or IDCA parts or components s described in paragraph (e)(7);

(v) A one-dimensional photon detector IRFPA described in paragraph (c)(2) and having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm and greater than 640 detector elements;

(vi) A one-dimensional or two-dimensional photon detector IRFPA described in paragraph (c)(2) having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm and greater than 256 detector elements;

(vii) A one-dimensional photon detector IRFPA described in paragraph (c)(3);

(viii) A two-dimensional photon detector IRFPA described in paragraph (c)(2) or (c)(4) having a peak response within the wavelength range exceeding 900 nm but not exceeding 2,500 nm, and greater than 111,000 detector elements;

(ix) A two-dimensional photon detector IRFPA described in paragraph (c)(4) having a peak response within the wavelength range exceeding 2,500 nm but not exceeding 30,000 nm;

(x) A multispectral infrared focal plane array described in paragraph (c)(2) or (c)(6); or

(xi) A charge multiplication IRFPA controlled in paragraph (c)(7) or (c)(8);

Note to paragraph (c)(12): The articles controlled by this paragraph have sufficient electronics to enable as a minimum the output of an analog or digital signal once power is applied.

Comment [26]: Captures item in normal commercial use and treated by France as dual use. See attachment Atom1024; microcam

Comment [27]: Item in normal commercial use and treated as dual use. See attachment Hamamatsu Sensor and Camera_a (G10768 series). 1D technology has been replaced by 2D fpas. No justification for old technology to be considered “crown jewels” especially when it is produced abroad.

Comment [28]: See attachment Hercules-MWIR

Comment [29]: 1D technology has been replaced by 2D fpas. No justification for old technology to be considered “crown jewel” especially when it is produced abroad. See attachment lynx-1.7-2048

Comment [30]: Foreign product in normal commercial use and treated abroad as dual use. See attachment U&U

Comment [31]: Foreign item in normal commercial use. See attachment cougar640

Comment [32]: See attachment XENICS xsw-640_module_a, NIT module_a

Comment [33]: See attachment Hercules-MWIR

Comment [34]: See attachment XENICS xsw-640_module_a, NIT module_a

Comment [35]: Foreign sources market claiming ITAR free. See attachment xco-640_modules, xco-640_ modules1; UofR

Comment [36]: See attachment NEO_HySpex, SASI-600v2, A3_Dual

(13) Binoculars, bioculars, monoculars, goggles, or head or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate any of the following, and specially designed electronics, optics, and displays therefor:

(i) An IIT controlled in this category; or

(ii) An infrared imaging camera core controlled in paragraph (c)(12)(i)-(xi);

Note to paragraph (c)(13): The articles controlled in this paragraph include binoculars, bioculars, monoculars, goggles, or head- or helmet-mounted imaging systems or equipment (including video-based articles having a separate near-to-eye display) that incorporate or are specially designed to incorporate an IRFPA or IIT article (e.g., IDCA, IRFPA assembly) and electronics separately.

(14) Targeting systems or equipment incorporating or specially designed to incorporate an article controlled in this category (e.g., pods, IBAS, SGFLIR, gunner TIS), and specially designed parts and components therefor;

(15) Infrared search and track (IRST) systems or equipment that incorporate or are specially designed to incorporate an article controlled in this category, and maintain positional or angular state of a target through time, and specially designed parts and components therefor;

(16) Infrared imaging systems or equipment (e.g., fully packaged cameras) incorporating or specially designed to incorporate an article controlled in this category, as follows, and specially designed electronics, optics, and displays therefor:

(i) Having two or more axes of active stabilization and a minimum root-mean-square (RMS) stabilization better (less) than 200 microradians;

Comment [37]: Insert specially designed due to lack of military parameters. Captures items in normal commercial use. See attachment 2012 Guide-IR, Russian i2

Comment [38]: Seeks to undo carve out which allowed for military I2 tubes when part of a commercial system would permit the system to be licensed as CCL; See attachment PI-MAX

Comment [39]: Would the UK ticam be caught ? Claims no ITAR license required.

Comment [40]: Insert specially designed as there are no military parameters being provided.

Comment [41]: Insert specially designed as there are no military parameters being specified and it captures commercial items in production. See attachment Selex

Comment [42]: Insert specially designed as there are no military parameters being provided and it captures commercially available products in production. See attachments A3_Dual, SASI-600v2, NEO_HySpex

(ii) Mobile reconnaissance, scout, or surveillance systems or equipment providing real-time target location at ranges greater than 5 km (e.g., LRAS, CIV, HTI, SeeSpot, MMS);

(iii) Fixed-site reconnaissance, surveillance or perimeter security systems or equipment having greater than 640 detector elements in any dimension;

(iv) Combat vehicle, tactical wheeled vehicle, naval vessel, or aircraft pilotage systems or equipment having a variable field of view or field of regard (e.g., electronic pan or tilt), and either an IRFPA article controlled in this subchapter with greater than 640 detector elements in any dimension, or an IIT controlled in this category (e.g., DAS, DVE, SeaFLIR, PNVS);

Note to paragraph (c)(16)(iv): This paragraph does not control distributed aperture sensors specially designed for civil automotive lane departure warning or collision avoidance.

(v) Multispectral imaging systems or equipment that either incorporate a multispectral IRFPA described in paragraph (c)(2) or (c)(6), or classify or identify military or intelligence targets or characteristics;

(vi) Automated missile detection or warning;

(vii) Hardened to withstand electromagnetic pulse (EMP) or chemical, biological, or radiological threats;

(viii) Incorporating mechanism(s) to reduce signature; or

(ix) Specially designed for military platforms controlled in Categories VI, VII or VIII (MT if designed or modified for unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);

(17) Terahertz imaging systems or equipment having a peak response in the frequency range exceeding 30 GHz but not exceeding 3000 GHz and having a resolution less (better) than 0.5 milliradians at a standoff range of 100 m;

Comment [43]: See attachment VarioCAM_HD_a ;

Comment [44]: Insert specially designed a there are no military parameters provided and appears to catch items that are in production and being sold commercially. See attachment Multispectral

Comment [45]: Insert specially designed as there are no military parameters provided and appears to catch items that are being sold commercially. See AMPS_Airborne Missile Protection System

Comment [46]: Insert specially designed as this may capture commercially available items for search and rescue.

(18) Near-to-eye display systems or equipment, specially designed for articles controlled in this subchapter;

(19) Systems or equipment that project radiometrically calibrated scenes directly into the entrance aperture of an electro-optical or infrared (EO/IR) sensor controlled in this subchapter within either the spectral band exceeding 10 nm but not exceeding 400 nm, or the spectral band exceeding 900 nm but not exceeding 30,000 nm; or

(20) Systems or equipment incorporating an infrared (IR) beacon or emitter specially designed for Identification Friend or Foe (IFF), and specially designed parts and components therefor;

(21) Developmental imaging systems or equipment funded by the Department of Defense.

Note 1 to paragraph (c)(21): This paragraph does not control imaging systems or equipment (a) in production; (b) determined to be subject to the EAR via a commodity jurisdiction determination (see §120.4 of this subchapter), or (c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications.

Note 2 to paragraph (c)(21): Note 1 does not apply to defense articles enumerated on the U.S. Munitions List, whether in production or development.

Note 3 to paragraph (c)(21): This provision is applicable to those contracts or other funding authorizations that are dated XXXX, 2016, or later.

Note to paragraph (c): A permanent encapsulated sensor assembly (e.g., sealed enclosure, vacuum package) prevents direct access to the IRFPA, disassembly of the sensor assembly, and removal of the IRFPA without destruction or damage to the IRFPA.

Comment [47]: Isn't this captured in e(12) ?

Comment [48]: Insert specially designed as this appears to capture items in commercial production. See attachment CI Systems Test Station FLIR, CI Systems Test Station, CI Systems SWIR Test Station

Comment [49]: There are a number of programs that DoD funds that are intended to be commercial to lower the cost of military derivatives.

Note to paragraphs (c)(1)- (c)(5), (c)(7), (c)(8), and (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x): The articles described in these paragraphs are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable. Articles are not subject to the EAR until integrated into the item subject to the EAR. Defense articles intended to be integrated, and technical data and defense services directly related thereto remain subject to the ITAR prior to integration. See paragraph (f) of this Category for enumerated technical data and software, and specific information subject to the EAR.

(d) Guidance, navigation, and control systems and equipment as follows:

(1) Guidance or navigation systems (e.g., inertial navigation systems, inertial measurement units, inertial reference units, attitude and heading reference systems) as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of a range greater than or equal to 300 km);

(i) Having a circle of equal probability (CEP) of position error rate less (better) than 0.35 nautical miles per hour;

(ii) Having a heading error or true north determination of less (better) than 0.50 mrad secant (latitude) (0.02865 degrees secant (latitude)); or

(iii) Specified to function at linear acceleration levels exceeding 25 g;

Note to (d)(1): For aircraft and unmanned aerial vehicle guidance or navigation systems, see Category VIII(e). For rocket or missile flight control and guidance systems (including guidance sets), see Category IV(h).

(2) Accelerometers having a bias stability of less (better) than 20 μg, a scale factor stability of less (better) than 20 parts per million, or capable of measuring greater than 100,000 g (MT if having a scale factor repeatability less (better) than 1250 ppm and bias repeatability less (better) than 1250 micro g or specified to function at acceleration levels greater than 100 g);

Note 1 to paragraph (d)(2): For weapon fuze accelerometers, see Category III(d) or IV(h).

Note 2 to paragraph (d)(2): MT designation does not include accelerometers that are designed to measure vibration or shock.

(3) Gyroscopes or angular rate sensors having an angle random walk of less (better) than 0.00125 degree per square root hour or having a bias stability less (better) than 0.0015 degrees per hour (MT if having a rated drift stability of less than 0.5 degrees (1 sigma or rms) per hour in a 1 g environment or specified to function at acceleration levels greater than 100 g);

(4) Mobile relative gravimeters, having automatic motion compensation, with an in-service accuracy of less (better) than 0.4 mGal (MT if designed or modified for airborne or marine use and having a time to steady-state registration of two minutes or less);

(5) Mobile gravity gradiometers having an accuracy of less (better) than 10 Eötvös squared per radian per second for any component of the gravity gradient tensor, and having a spatial gravity wavelength resolution of 50 m or less (MT if designed or modified for airborne or marine use);

Note to paragraph (d)(5): "Eötvös" is a unit of acceleration divided by distance that was used in conjunction with the older centimeter-gram-second system of units. The Eötvös is defined as 1/1,000,000,000 Galileo (Gal) per centimeter.

(6) Global Navigation Satellite System (GNSS) receiving equipment, as follows, and specially designed parts and components therefor:

(i) Global Navigation Satellite System (GNSS) receiving equipment specially designed for military applications (MT if designed or modified for airborne applications and capable of providing navigation information at speeds in excess of 600 m/s);

(ii) Global Positioning System (GPS) receiving equipment specially designed for encryption or decryption (e.g., Y-Code, M-Code) of GPS precise positioning service (PPS) signals (MT if designed or modified for airborne applications);

(iii) GPS receiving equipment specially designed for use with a null steering antenna, an electronically steerable antenna, or including a null steering antenna designed to reduce or avoid jamming signals (MT if designed or modified for airborne applications); or

Note to paragraph (6)(iii): The articles described in this paragraph are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR. Articles do not become subject to the EAR until integrated into the item subject to the EAR. Export, reexport, retransfer, or temporary import of, and technical data and defense services directly related to, defense articles intended to be integrated, remain subject to the ITAR.

(iv) GPS receiving equipment specially designed for use with rockets, missiles, space launch vehicles (SLVs), drones, or unmanned air vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km (MT);

Note to paragraph (6)(iv): “Payload” is the total mass that can be carried or delivered by the specified rocket, missile, SLV, drone or unmanned aerial vehicle that is not used to maintain flight**.** For definition of “range” as it pertains to rocket systems, see note 1 to paragraph (a) of USML Category IV. For definition of “range” as it pertains to aircraft systems, see note to paragraph (a) of USML Category VIII.

(7) GNSS anti-jam systems employing adaptive antennas that have a minimum of four antenna elements, add 35 dB or greater anti-jam margin, and produce nulls in the direction of jammers or high-gain beams in the direction of satellites at any ranging code frequency;

(8) GNSS security devices (e.g., Selective Availability Anti-Spoofing Modules, Security Modules, and Auxiliary Output Chips), Selective Availability Anti-Spoofing Module (SAASM), Security Module (SM) and Auxiliary Output Chip (AOC) chips; or

(9) Developmental guidance, navigation, or control devices, systems or equipment funded by the Department of Defense (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of a range equal to or greater than 300 km);

Note 1 to paragraph (d)(9): This paragraph does not control guidance, navigation, or control, systems, or equipment (a) in production, (b) determined to be subject to the EAR via a commodity jurisdiction determination (see § 120.4 of this subchapter), or (c) identified in the relevant Department of Defense contract or other funding authorization as being developed for both civil and military applications.

Note 2 to paragraph (d)(9): Note 1 does not apply to defense articles enumerated on the U.S. Munitions List, whether in production or development.

Note 3 to paragraph (d)(9): This provision is applicable to those contracts or other funding authorizations that are dated XXXX, 2016, or later.

Note 4 to paragraph (d)(9): For definition of "range" as it pertains to rocket systems, see note 1 to paragraph (a) of USML Category IV. For definition of "range" as it pertains to aircraft systems, see note to paragraph (a) of USML Category VIII.

(e) Parts, components, accessories, attachments, and associated equipment as follows:

(1) Optical sensors having a spectral filter for systems or equipment controlled in Category XI(a)(4), or optical sensor assemblies that provide threat warning or tracking for systems or equipment controlled in Category XI(a)(4) and specially designed optics and electronics therefor;

(2) Image intensifier tube (IIT) parts and components as follows:

(i) Microchannel plates having a hole pitch (center-to-center spacing) of 12 µm or less;

(ii) Multialkali photocathodes (e.g., S-20 and S-25) having a luminous sensitivity exceeding 500 microamps per lumen;

(iii) III/V compound semiconductor (e.g., GaAs or GaInAs) photocathodes and transferred electron photocathodes having a radiant sensitivity exceeding 20 mA/W;

(iv) Electron sensing devices with detectors having a non-binned center-to-center spacing less than 100 µm, and either achieving charge multiplication within the vacuum space other than by a microchannel plate or specially designed for operation with a microchannel plate;

(v) Phosphor screens, including output faceplates, specially designed for IITs controlled in this category;

(vi) Miniature autogated power supplies providing internal sensing and control of the photocathode to increase the dynamic range of IITs controlled in this category; or

Comment [50]: Insert specially designed as there are no military parameters provided. Cannot be "crown jewel" due to foreign availability and commercial production. See attachment mcp_a

Comment [51]: Insert specially designed as this entry refers to Gen 2 technology which is not produced in the US any longer and cannot be a "crown jewel".

(vii) Fiber-optic inverters, couplers or tapers specially designed for IITs controlled in this category;

(3) Wafers incorporating structures for either a ROIC controlled in paragraph (e)(4) or (e)(5), or an IRFPA or detector elements therefor controlled in paragraph (c)(2);

(4) Read-Out Integrated Circuits (ROICs) specially designed for an IRFPA controlled in paragraph (c)(2) or detector elements therefor, as follows:

(i) one-dimensional photon detector IRFPA having greater than 640 detector elements;

(ii) two-dimensional photon detector IRFPA having greater than 256 detector elements;

(iii) a microbolometer IRFPA having greater than 19,200 elements; or

(iv) multispectral IRFPA;

<u>Note to paragraph (e)(4)</u>: ROICs are specially designed for an infrared focal plane array detector even if the detector is incorporated into an item that is not enumerated on the U.S. Munitions List.

(5) ROICs specially designed for a camera/core/packaged IRFPA subject to the controls of this Subchapter;

(6) Vacuum packages or other sealed enclosures for an IRFPA or IIT controlled in paragraph (c) of this category specially designed for incorporation or integration into an article controlled in paragraphs (a), (b), or (c) of this category;

(7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components, as follows:

(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

(ii) Active cold fingers;

Comment [JD52]: Wafers have previously not been listed in the USML. “incorporating structures” is undefined and therefore open to interpretation.

Comment [53]: Insert specially designed in front of ROIC and remove it from IRFPA as there are no military parameters provided. Most ROICs are general purpose and can be coupled to different detector arrays or different sizes.

Comment [54]: 1D technology has been replaced by 2D. Old technology should not be considered to be “crown jewels” and removed from ITAR control entirely.

Comment [55]: See attachment NIT ROIC-2014

Comment [56]: ROICS are needed for all commercial applications. Given the lack of military equities in the uncooled market, this entry should be removed from ITAR control entirely. See Maxtech data.

Comment [57]: What does this entry capture that is not covered in e(4).

Comment [58]: Insert specially designed as there are not military parameters provided to determine when an item is a munitions.

Comment [59]: The parameters provided capture items in normal commercial use and available from foreign sources. Not crown jewels. See attachment K508_a

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b) or (c) of this category;

(8) IRFPA Joule-Thomson (JT) self-regulating cryostats specially designed for articles controlled in this subchapter;

(9) Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings, specially designed for any article controlled in this category;

(10) Drive, control, signal or image processing electronics, specially designed for articles controlled in this category;

(11) Signal processing electronics, attachments or accessories that provide:

(i) Automatic or aided detection and recognition, classification, identification or discrimination of military or intelligence items;

(ii) Multi-sensor fusion other than image blending; or

(iii) Target aim point adjustment;

Note to paragraph (e)(11)(ii): Multi-sensor fusion refers to automatically combining imagery or information from two or more sensors, including at least one article controlled in this category, to improve classification, identification, or tracking of targets relative to any of the individual sensors.

(12) Near-to-eye displays specially designed for articles controlled in this category;

(13) Resonators, receivers, transmitters, modulators, gain media, and drive electronics or frequency converters specially designed for laser systems or equipment controlled in this category;

(14) Two-dimensional infrared scene projector emitter arrays (i.e., resistive arrays) that emit infrared radiation within the 900 nm to 30,000 nm wavelength range; or

Comment [60]: There are ECCNs being proposed in the companion rule (i.e. 6A615) that would overlap with this language. Why does this leave off the optical materials used in 615 as parameters? What is the need to control items available from Germany, Israel, Japan, and the PRC? Perhaps the 615 language needs to be incorporated here and deleted from the companion rule. See attachment Optec(1), Optec(2), Optec(3). Specifically infrared lenses has never been an item listed on the USML and is not a listed item on the Wassenaar munitions list. This technology is inherently dual-use and should fall under the jurisdiction of the CCL.

Comment [61]: Insert specially designed since there is no definition/parameters for military or intelligence items provided

Comment [62]: Foreign availability of capability which is treated as dual use. Note reference to no ITAR restrictions. See attachments meerkat_fusion and meerkat-fusion camera.

Comment [63]: Isn't this already captured in C(18) ?

(15) Any part, component, accessory, attachment, or associated equipment, that:

(i) is “classified”;

(ii) contains “classified” software;

(iii) is manufactured using “classified” production data; or

(iv) is being developed using “classified” information.

Note to paragraph (e)(15): “Classified” means classified pursuant to Executive Order 13526, or predecessor order, and a security classification guide developed pursuant thereto or equivalent, or to the corresponding classification rules of another government.

Note to paragraph (e): The articles described in this paragraph are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the EAR, and cannot be removed without destruction or damage to the article or render the item inoperable. Articles are not subject to the EAR until integrated into the item subject to the EAR. Defense articles intended to be integrated, and technical data and defense services directly related thereto, remain subject to the ITAR prior to integration. See paragraph (f) of this Category for enumerated technical data and software, and specific information subject to the EAR.

*(f) Technical data (as defined in §120.10 of this subchapter) and defense services (as defined in §120.9 of this subchapter) directly related to the defense articles enumerated in paragraphs (a) through (e) of this Category. (See §125.4 of this subchapter for exemptions.) (MT for technical data and defense services related to articles designated as such.)

Note 1 to paragraph (f): Technical data and defense services directly related to image intensifier tubes and specially designed parts and components therefor controlled in paragraph (c)(1), infrared focal plane arrays (IRFPAs) and detector elements therefor controlled in paragraph (c)(2), integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9), wafers incorporating IRFPA or ROIC structures controlled in paragraph (e)(3), and specially designed readout integrated circuits (ROICs) controlled in paragraphs (e)(4) and (e)(5), remain subject to the ITAR even if the technical data or defense services could also apply to items subject to the EAR.

Note 2 to paragraph (f): Software and technical data include:

A. Design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters) for lasers described in paragraphs (b)(6) and (b)(9)-(13), IITs controlled in paragraph (c)(1) and their parts and components controlled in paragraph (e)(2) (including tube sealing techniques, interface techniques within the vacuum space for photocathodes, microchannel plates, phosphor screens, input glass-window faceplates, input or output fiber optics (e.g., inverter)), IRFPAs and detector elements therefor controlled in paragraph (c)(2), integrated IRFPA dewar cooler assemblies (IDCAs) controlled in paragraph (c)(9),wafers incorporating structures for an IRFPA and detector elements therefor controlled in paragraph (c)(2) or structures for ROICs controlled in paragraph (e)(4) or (e)(5), and specially designed ROICs controlled in paragraphs (e)(4) and (e)(5) (including bonding or mating (e.g., hybridization of IRFPA detectors and ROICs), prediction or optimization of IRFPAs or ROICs at cryogenic temperatures, junction formation, passivation).

Note to paragraph A: Technical data does not include information directly related to basic operating instructions, testing results, incorporating or integrating IRFPAs into higher level packaged assemblies not enumerated in this category, or external interface control documentation associated with such assemblies or assemblies subject to the EAR, provided such information does not include design methodology, engineering analysis, or manufacturing know-how for a USML controlled IRFPA.

B. Software that converts an article controlled in this category into an item subject to the EAR or an item subject to the EAR into an article controlled in this category is directly related to the defense article controlled in this category. When a defense article has been converted into an item subject to the EAR through software, the presence of the software that prevents the item from meeting or exceeding a USML control parameter does not make the item subject to the ITAR.

C. EO/IR simulation or projection system software that replicates via simulation either the output data or information provided by any article controlled in this category, a radiometrically calibrated spectral signature of any article controlled in this subchapter, volumetric effects of plumes or military operational obscurants, or countermeasure effects.

Note 3 to paragraph (f): Technology for incorporating or integrating IRFPAs into permanent encapsulated sensor assemblies subject to the EAR, or integrating such assemblies into an item subject to the EAR, and integrating IITs into an item subject to the EAR, including integrating items subject to the EAR into foreign military commodities outside the United States, is subject to the EAR.

(g)-(w) [Reserved]

(x) Commodities, software, and technology subject to the EAR (see §120.42 of this subchapter) used in or with defense articles controlled in this category.

Note to paragraph (x): Use of this paragraph is limited to license applications for defense articles controlled in this category where the purchase documentation includes commodities, software, or technology subject to the EAR (see §123.1(b) of this subchapter).

* * * * *

4. Section 121.1 is amended by reserving paragraph (c) in U.S. Munitions List Category XV.

____
(Date)

____
Rose E. Gottemoeller,
Under Secretary,
Arms Control and International Security,
Department of State.

VISIONMAP
Digital mapping systems

The largest footprint in the market

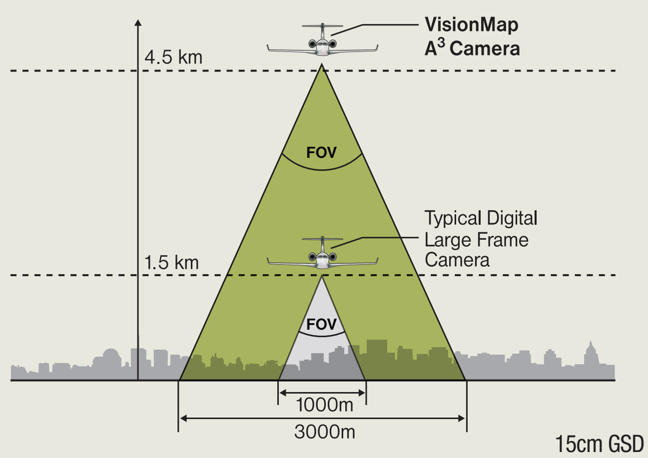
A3 Airborne Digital Mapping Camera

Airborne

The well known A3 airborne digital camera has already become synonymous with productivity in the aerial survey and mapping industry

With the largest footprint of 60,000 pixels across flight track, efficient imagery collection of large areas and high-resolution vertical and oblique imagery, A3 airborne digital camera is the most advanced mapping camera available today

Larger coverage, same resolution



A3 largest footprint

With 60,000 pixels across flight track, A3 presents by far the largest footprint of aerial cameras available in the market.

Superior high-resolution imagery

A3 camera allows your airplane to fly higher, faster and with wider flight line spacing, covering a larger area than other systems do. A3 camera's long focal length capture high-resolution imagery from higher altitudes, simplifying the flight planning and operations of survey projects.

Multiple products in one flight

With a wide field-of-view (up to 109 degrees), A3 collects multi-directional images of each point in both vertical and oblique angles.

Compact system, easy installation

A3 was designed for complete ease of use, with compact size and light weight. The camera is easy to install and use on most camera-ready aircrafts.

A3 aerial survey productivity

GSD (m)	0.03	0.05	0.10	0.15	0.20	0.25	0.30
Altitude above ground (feet)	3,281	5,468	10,936	16,404	21,872	27,340	32,808
Typical ground speed (knots)	160	180	210	245	275	325	370
Flight-line distance (m)	237	529	2,184	3,728	5,596	7,809	10,392
Footprint width (m)	590	1,322	5,569	9,351	14,009	19,451	25,957
Net coverage for orthophoto production (km^2/hour)	**70**	**176**	**849**	**1,692**	**2,850**	**4,700**	**7,121**

A3/A3 CIR specification summary

Camera Type	A3/ A3 CIR
Mechanical Specifications	
Total weight (kg)	35
Size (cm)	53 x 53 x 53
Optical Specifications	
Number of lenses	2
Focal length (mm)	300
Aperture	f/4.5
Exposure principle	Global shutter
CCD type	KAI-11002
CCD number	2
CCD dynamic range (bit)	12
CCD pixel size (μ)	9
CCD array (single frame size,pixel)	4006 x 2666
Double frame Size (pixel)	7812 x 2666
One lens FOV: Along flight line (degree) Across flight line (degree)	6.58° 4.58°
Spectral characteristics (nm)	R 600-740 G 510-580 B 415-515 A3 CIR : NIR 690-780
Operational Specifications	
Frame rate (fps)	7.5
Max operational FOV (degree)	109°
Max number of frames in one sweep	66 A3 CIR: RGB 33; NIR 33
Max footprint size (pixel)	~ 62,000 x 8,000 A3 CIR ~ 62,000 x 4,000
Motion compensation	(FMC,RMC,VC) Forward, Roll, Vibration

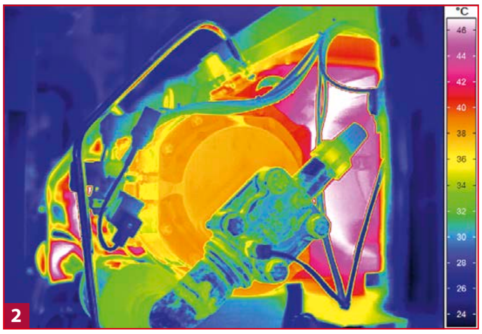
Camera Type	A3/ A3 CIR
Image Specifications	
Image geometry	Central projection
Color	RGB A3 CIR: RGB + NIR
Image file format	JPEG2000, TIFF
Flight Specifications	
Minimal flight altitude (feet)	2,700
GSD at minimal flight altitude (cm)	2.5
Aircraft ground speed (knot)	50 – 500
Forward overlap between sweeps in one flight line (%)	30% - 90%
Image on-the-fly viewing	Yes
Temperature (°C)	-15° to 55°
On-board Storage	
On-board storage capacity (TB)	1.0
On-board storage type	SSD - Solid State Drive
On-board storage exchangeability	Yes
System Specifications	
DC supply voltage (V)	28V (26V-32V)
Current consumption (A)	2.5 A (Max–4A)
Power consumption (W)	<120W/28 VDC
GPS type	L1/L2
Image download interface	Gb Ethernet
Writing bit rate (MB/sec)	165

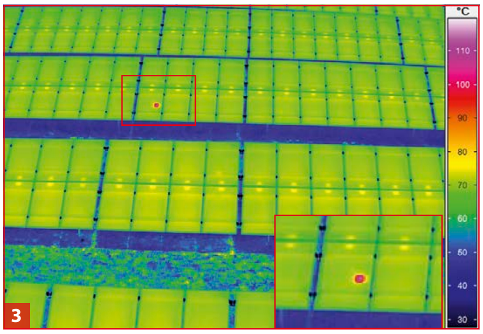
About VisionMap

VisionMap LTD. is a leading provider of state-of-the art digital automatic aerial survey and mapping systems. VisionMap created an innovative data collection and data processing system which optimized geospatial imagery collection and processing, setting a new standard for productivity. VisionMap systems are successfully deployed worldwide.

VarioCAM® High Definition

Thermographic Solution for Universal Use





1) VarioCAM® HD from Jenoptik
2) Transmission
3) Photovoltaic power plant

InfraTec

Europe's leading specialist for infrared sensors and measurement technology

Microbolometer camera with up to (1,024 × 768) IR pixels
Optomechanical MicroScan with up to (2,048 × 1,536) IR pixels
Frame rate of up to 240 Hz, GigE-Vision interface
Integrated light-sensitive digital 8 MP camera
5.6" colour TFT display with (1,280 × 800) pixels
Laser rangefinder and GPS sensor
Wireless camera control and data acquisition via WLAN
Made in Germany

www.InfraTec.eu

JENOPTIK

Latest information on the internet.

Spectral range	(7.5 ... 14) µm
Detector	Uncooled Microbolometer Focal Plane Array
Detector format (IR pixels)	(1,024 × 768) with built-in opto-mechanical high-precision scan unit (2,048 × 1,536)* (640 × 480) with built-in opto-mechanical high-precision scan unit (1,280 × 960)*
Temperature measuring range	(-40 ... 1,200) °C, > 2,000 °C*
Measurement accuracy	± 1 °C or ± 1 %*, otherwise ± 1.5 °C or ± 1.5 %
Temperature resolution @ 30 °C	Better than 0.03 K*, otherwise better than 0.05 K
Frame rate	Fullframe: 30 Hz (1,024 × 768), subframe formats*: 60 Hz (640 × 480) / 120 Hz (384 × 288) / 240 Hz (1,024 × 96) Fullframe: 60 Hz (640 × 480), subframe formats*: 120 Hz (384 × 288) / 240 Hz (640 × 120)
Image storage	SDHC-card, GigE-Vision up to 240 Hz, internal real-time storage
Lens mount	Bayonet to comfortably switch objectives, automatic objective detection and data transfer
Focus	Motor-driven, automatic or manual, accurately adjustable, laser-supported autofocus
Zoom	Up to 32x digital, stepless
Digital colour video camera	8 Megapixels, with a LED video light, vision mixer and cross-fade feature
Dynamic range	16 bit
Interfaces	GigE-Vision, DVI-D, C-Video, RS232, Trigger, Analog output*, Digital I / O*,WLAN, USB 2.0, Bluetooth, GPS
Tripod adapter	1/4 " photo thread
Power supply	Lithium-Ion battery (quick rechargeable, with status display), AC adapter
Laser range finder*	Red semiconductor laser, laser safety class 2, range up to 70 m
Display	5.6 " colour TFT display (1,280 × 800) pixels, daylight suited
Colour viewfinder*	Tiltable colour viewfinder with diopter compensation
Single-handed operation	Intuitive operation with ergonomically arranged function keys and multifunctional joystick, programmable keys
Storage and operation temperature	(-40 ... 70) °C, (-25 ... 50) °C
Protection degree	IP54, IEC 529
Impact strength/vibration resistance in operation	25 G (IEC 68 - 2 - 29), 2 G (IEC 68 - 2 - 6)
Dimensions, weight	(210 × 125 × 55) mm, 1.7 kg
Automatic functions	Autofocus, permanent autofocus, automatic distance indicator, distance-dependent calculation of permitted pixel size, Autoimage, Autolevel, Min./Max. temperature alarm: visual/acoustic, alarm triggered image storage
Measurement functions	8 free choosable, movable measurement fields/-points, automatic hot/cold spot display: global and internal defined measurement fields, differential temperature measurement: temporally/locally, temperature profile, histogram, differential image, isotherms display
Further functions	EverSharp function (multifocus), shutter-free operation, temperature alarm, image merging, synchronous display of thermal and visual image in real-time
Analysis and evaluation software*	IRBIS® 3, IRBIS® 3 professional, IRBIS® 3 view, IRBIS® 3 plus, IRBIS® 3 remote HD, IRBIS® 3 online, IRBIS® 3 process, IRBIS® 3 active, IRBIS® 3 mosaic, IRBIS® 3 vision, FORNAX 2.0

* Depending on model

For the first time a handheld thermographic microbolometer cameras with a **detector format of (1,024 × 768) IR pixels** is available: The **VarioCAM® HD** is manufactured by the **German manufacturer Jenoptik**. It comes with a resolution 2.5 higher than pevious high-class models. In connection with the outstanding thermal resolution and **unique precision optics**, crystal clear high-precision thermal images can be taken. Large test objects can be captured thermographically with unprecedented efficiency.

Detector format (IR pixels)		**(640 × 480)**	**(1,024 × 768)**
Lens	Focal distance (mm)	FOV (°)	FOV (°)
Super wide-angle lens	7.5	(93.7 × 77.3)	(98.5 × 82.1)
Wide-angle lens	15	(56.1 × 43.6)	(60.3 × 47.0)
Standard lens	30	(29.9 × 22.6)	(32.4 × 25.6)
Telephoto lens	60	(15.2 × 11.4)	(16.5 × 12.4)
Telephoto lens	120	(7.6 × 5.7)	(8.3 × 6.2)

Macro and microscopic lenses	Min. object distance (mm)	Pixel (µm)	Pixel (µm)
Close-Up 0.2× for 30 mm	69.7	75	51
Close-Up 0.5× for 30 mm	32.6	42	29
Close-Up 0.5× for 60 mm	78.3	42	28
Microscopic lens M=1.0×	40	25	17

InfraTec GmbH
Infrarotsensorik und Messtechnik

Gostritzer Straße 61 - 63
01217 Dresden / GERMANY
Phone: +49 351 871-8630
Fax: +49 351 871-8727
E-mail: thermo@InfraTec.de

Presentation to SITAC - Sensors & Instrumentation Technical Advisory Committee Meeting

Professor Judy Pipher

Department of Physics and Astronomy

University of Rochester

OCTOBER 28, 2014

Export Controls and University Research

- **Many times export controls are applied to equipment "purchased" by university researchers for basic fundamental research**
- **Sometimes this reflects excess caution by Industry**
- **Sometimes this reflects lack of understanding by government agencies such as Dept. of Commerce, or Dept. of State**

The net result is that university fundamental research is adversely affected, as I shall show through several examples.

Rochester Faculty and Staff Consulted

- **Duncan Moore, Optics (part of Engineering school)**
- **Jim Zavislan, Optics**
- **Jim Fienup, Optics**
- **Jannick Rolland, Optics**
- **John Schoen, Laboratory for Laser Energetics (LLE)**
- **Jonathan Ellis, Mechanical Engineering and Optics**
- **John Tarduno, Earth and Environmental Sciences (EES)**
- **Bill Forrest, Physics and Astronomy**
- **Dan Watson, Physics and Astronomy**
- **Gunta Liders, Assoc. VP, Office of Research and Project Administration (ORPA)**

Thermal Infrared Detector Arrays

- My specific interest is development of thermal infrared arrays with small well depths and dynamic ranges suitable for low-background IR space astronomy, but NOT military use, NOT earth-looking devices thus NOT surveillance
- They are designed for experiments exploiting passive cooling in space for astronomy
- THESE ARRAYS ARE NOT DUAL-USE and are being developed by us in collaboration with aerospace companies under NASA contracts
- Typically ITAR is introduced by industry on their documents and contract language

Current Industrial Partner Teledyne

- **Teledyne is producing for our group under our specifications, 1024 x 1024 HgCdTe (MCT) arrays, cutoff wavelength 10 μm under a NASA grant, for the NEOCam space mission**
- **We insist on the astronomy H1RG readout, and techniques to increase the diode capacitance (well depth) according to Pipher/Forrest group prescription**
- **NEOCam requires noise < 30 electrons, dark current < 200 electrons/s, well depth > 45,000 electrons for the NEOCam experiment, at a focal plane temperature of 35-40K for the 10 μm arrays**
- **Contrast this with military requirements of noise ~ 1000 electrons, dark current of 1,000,000 electrons/s and well depths of 10 million electrons, operating at as high a temperature as feasible**

New NASA Grant

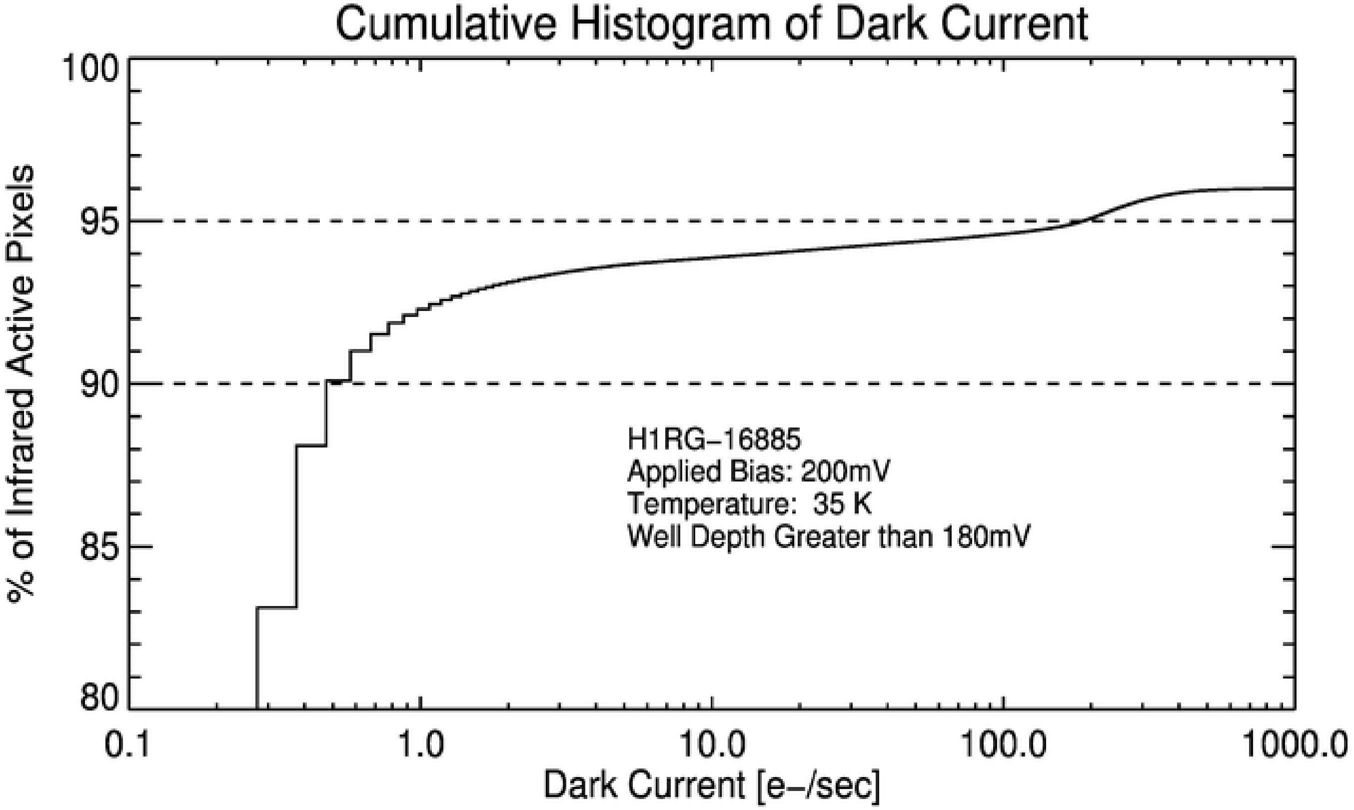
- **Recently obtained a new NASA grant to extend cutoff wavelength to 13 then 15 μm at a focal plane temperature of 26K: very important for astronomical space missions**
- **Took 8 months of negotiation to obtain suitable contract language acceptable to the university**

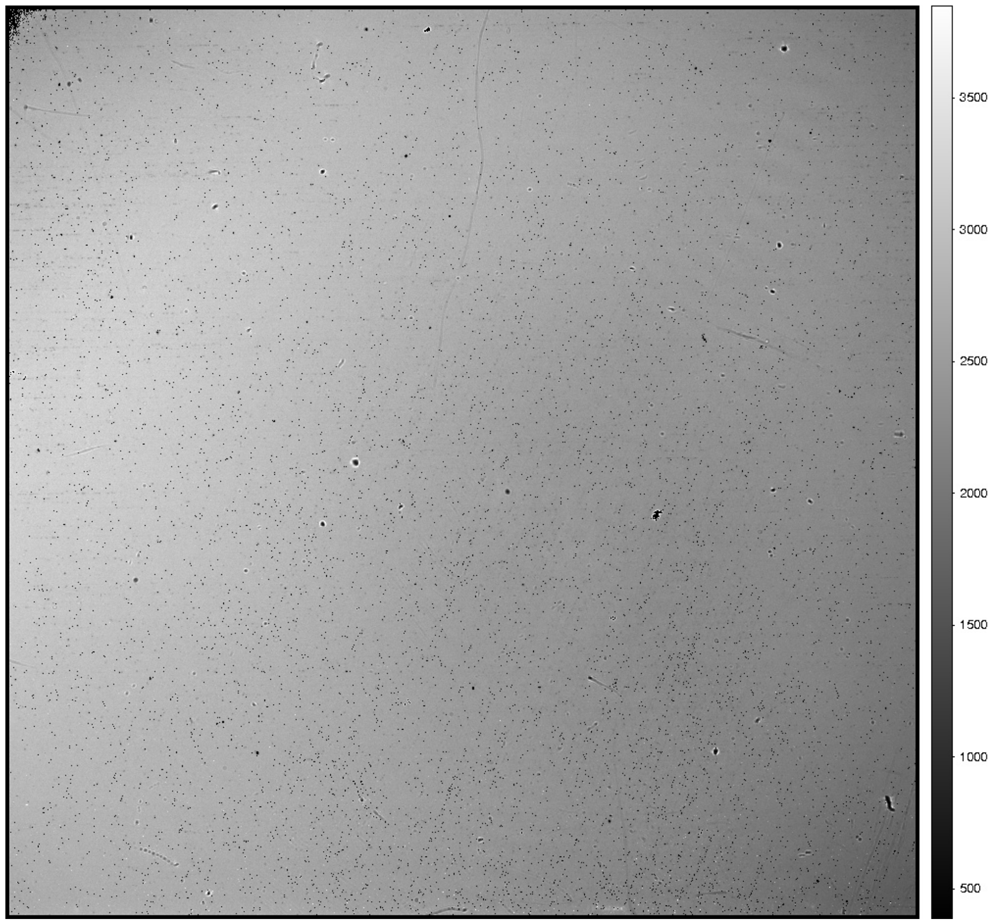
"University of Rochester shall share with Teledyne any test data generated under this contract. Also, due to ITAR restrictions and proprietary information concerns, Teledyne shall review any article by the University of Rochester resulting from this contract before publication.“

Provisions, Impact on Research

- **Our office of research and project administration (ORPA) accepted this under the university basic research exemption, BUT insist that we maintain**
  - **Special keys to labs and offices (janitors have no access when we are not present)**
  - **No foreign grad students can work on the devices**
  - **No unaccompanied persons and no foreign nationals in the lab**
  - **Protected web sites including email**
  - **The publication mandate passed muster ONLY because we collaborate with Teledyne Physicists, and they are co-authors who must approve the paper anyway**
- **ANNOYING, BUT DOABLE**

Published 10 μm results, with Teledyne Co-authors

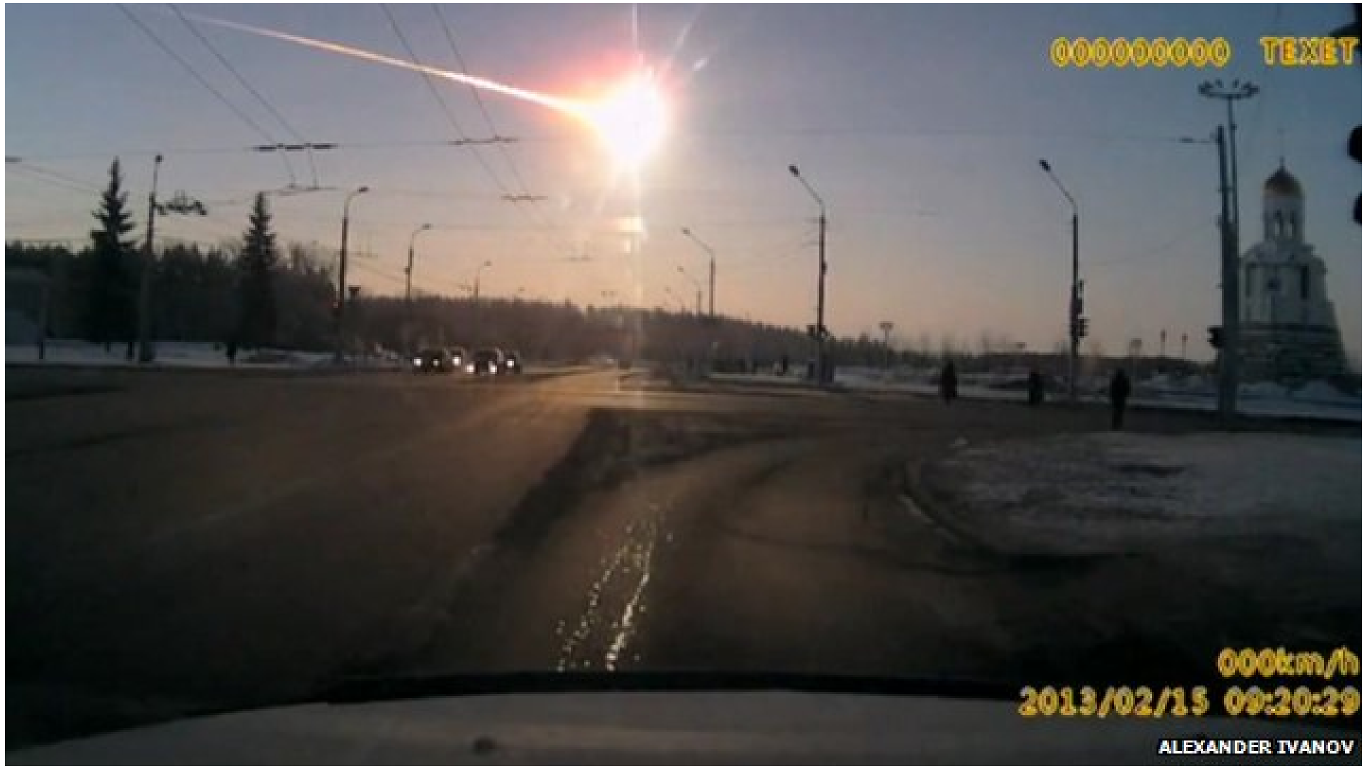




Quantum efficiency and uniformity excellent

NEOCam (Dr. Amy Mainzer, JPL, PI)

- **A proposed IR mission to survey all Near Earth Objects (asteroids and comets) and identify their properties, orbits, and evolutionary significance**
- **Addresses congressional mandate to inform US of potentially hazardous objects which may impact the Earth, like Chelyabinsk**
- **Augments existing visible observations – identify very dark NEOs (in the visible) by their thermal emission at 10 μm with LWIR arrays we developed**



Chelyabinsk. NEOCam will interrupt the survey to perform targeted follow-up of imminent collision risks

Raytheon Contract

- **Raytheon asked Pipher/Forrest lab to evaluate some developmental competing 10 μm cutoff arrays bonded to a dual-use multiplexer readout**
- **ITAR restrictions in terms and conditions were emphasized: ORPA stated research could not be conducted onsite**
- **Exelis (formerly ITT) collaborators on a different project allowed us to test in their lab – all our equipment had to be moved, and even data could not be reduced onsite at the university**
- **Delays to project completion because of transport of equipment, and no after hours access**
- **ONLY WAY WE COULD CONDUCT THIS RESEARCH**

Foreign Collaborators on Space Missions

- **I act as liaison on the Canadian FGS/NIRISS (fine guidance sensor and near-IR imager and slitless spectrograph) team for JWST (James Webb Space telescope) since I have dual citizenship**
- **ITAR regulations prohibited Canadian involvement in development details of the MWIR HgCdTe detector arrays produced by Teledyne**
- **As liaison I was able to hear relevant details during the process of development, including during a GSFC Tiger Team investigating failures in the JWST detector arrays**
- **Canadian investigators were essentially held hostage, and refused to pay for replacement arrays: GSFC paid for them**
- **A second example: ESA was interested in LWIR detector technology for DARWIN, but could only buy black boxes from US Industry – no involvement with design**

LLE Experience

- **John Schoen describes similar invasive requirements to specific research, although he at least is able to have work described below done at LLE (similar to our Teledyne work)**
- **Export controls on high intensity laser threshold coatings to optical elements**
- **Their work-around – the control specifications for the coatings were devised by US citizens, and kept in a specially locked area under a technology control plan. Technicians who apply the coatings are not privy to the specifications.**
- **John has a long-term concern about controls relating to high intensity lasers – too much room for interpretation**

Engineering Colleagues' Experience

- **Colleagues at the engineering schools at University of Rochester (Optics, Mechanical Engineering) have not been able to resolve many issues with ORPA and/or their funding agencies w.r.t. Export Controls**
- **Engineering graduate programs have ~50% foreign nationals in experimental fields**
- **Specific examples follow**

Engineering Colleagues' Experience continued

- **Duncan Moore and Jim Zavislan are building instruments for non-military application, but need to purchase an IR camera for the instrument**
- **Moore's 2-5 μm interferometer contract would meet the basic research exemption, but the FLIR cameras SC 6700 and A6700sc are ITAR!! - uses InSb detector arrays**
- **There are MANY such IR cameras available around the world for sale and some even advertise "no ITAR controlled components"**
- **Moore's research will lead to measurements of optical materials for refractive optics – existing lenses are either very complex, or do not cover the required wavelength range**

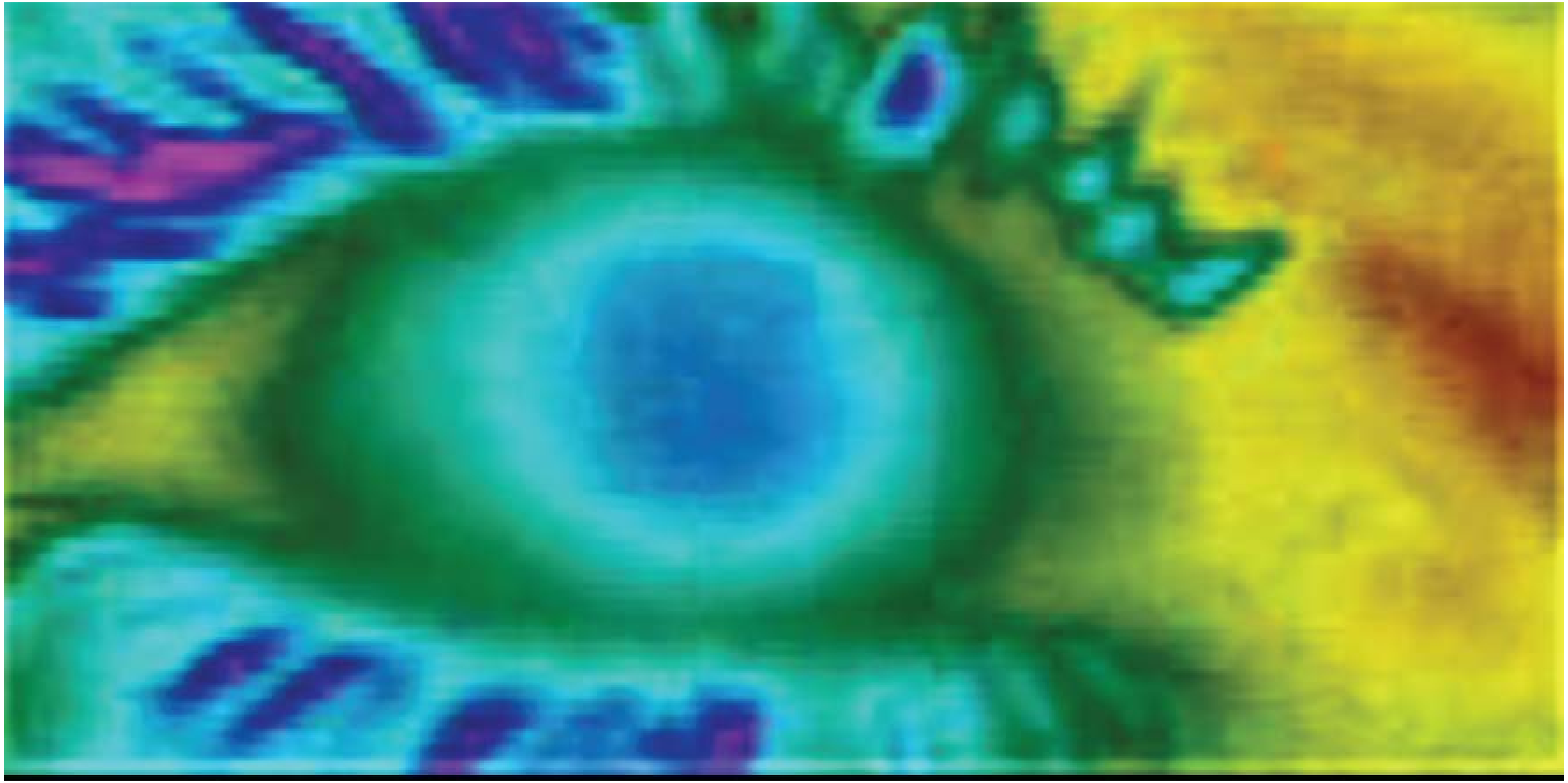
Engineering Colleagues' Experience continued

- **Jon Ellis in Engineering is building next generation instruments, unrelated to military objectives (e.g. building a distance measuring interferometer), but design principles he uses and instrumentation he wishes to use are deemed Dual Use by government**
- **Dual use categories comprise a gray area; not sufficiently definitive**
- **Jon has had two awarded contracts turned down by ORPA, and two others modified with reduced budgets due to ITAR**
- **All of his research is fundamental but took 3 months negotiations between DoD and ORPA for awarded contracts accepted by ORPA**

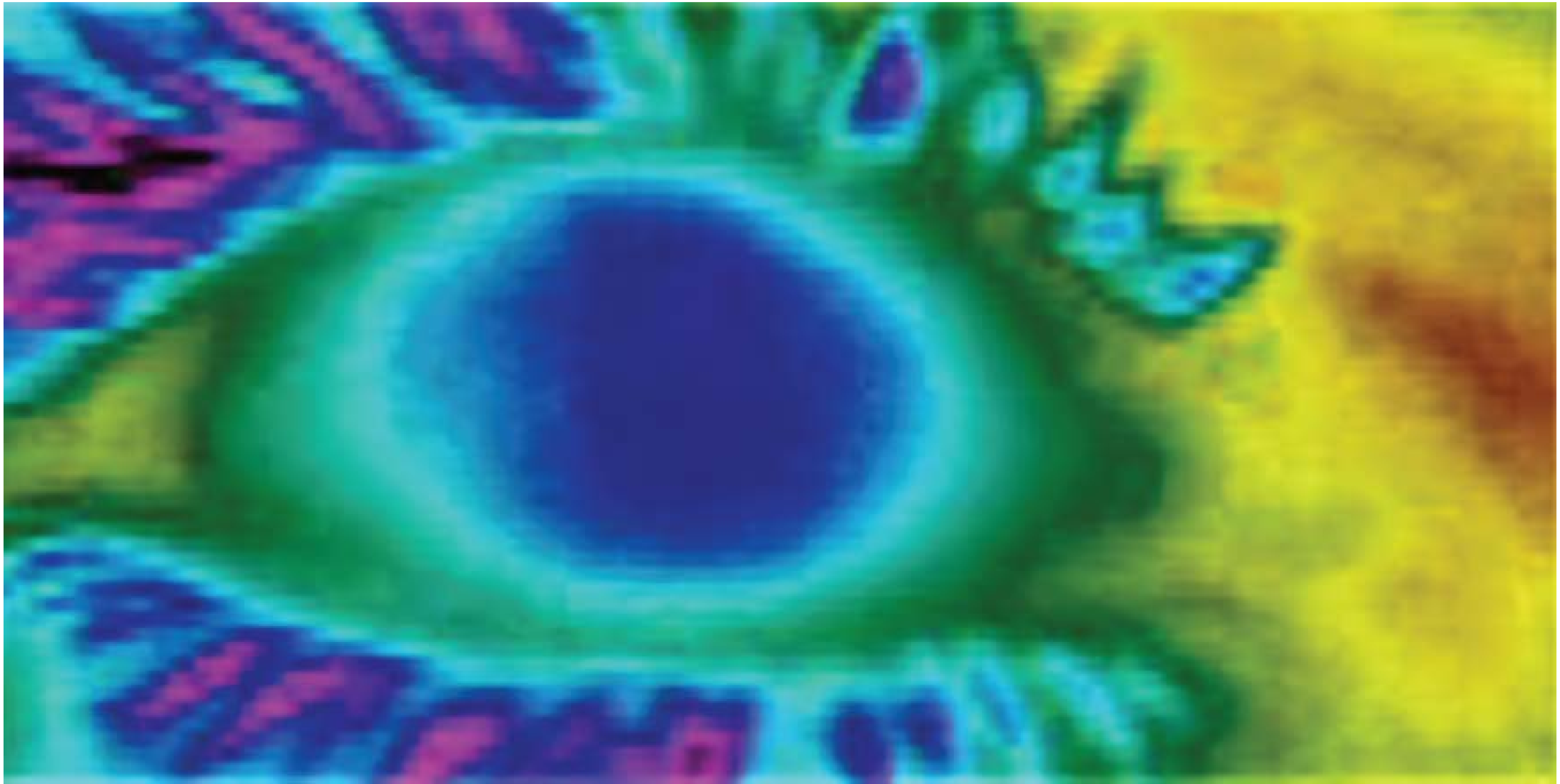
Engineering Colleagues' Experience continued

- **Jim Zavislan also requires a 3-5 μm camera for research he is conducting to explore the emissivity of the eye's tear film as an indicator of health - POTENTIALLY EXTREMELY IMPORTANT DIAGNOSTIC FOR HEALTH CARE**
- **He needs emissivity over the complete 3-7 and 7-14 μm bands OR the 7-10 and 10-12 μm bands to evaluate the tear's climate**
- **Commercial microbolometer LWIR cameras are available, and are not ITAR**
- **Thermal images of patient's eye on next 2 slides – if emissivity constant, intensity is proxy for temperature**

LWIR Thermal image of dry eye patient immediately after blink



LWIR Thermal image of dry eye patient 5 sec after blink



Engineering Colleagues' Experience continued

- **Jim Fienup is interested in optical reconnaissance and surveillance, issues related to space telescopes for astronomy, in microwave synthetic-aperture radar – and cannot pursue these because of export controls**
- **He has had to turn down multiple subcontract opportunities with different aerospace contractors on DARPA projects because ORPA would not allow anything with ITAR provisions in the prime contract, even when the work at UR would not have ITAR content. Once DARPA refused to deal with paperwork relating to the university basic research exemption**
- **One unique workaround found whereby students were funded on unrestricted IR&D funds from the contractor on a grant, synergistic with the DARPA effort, but not formally part of it. DARPA was aware of the workaround.**

Engineering Colleagues’ Experience continued

- **Jannick Rolland (recipient of the OSA David Richardson Medal 2014) is sufficiently concerned that she does not apply for 30% of the potential grants for which she is qualified and interested**
- **Her instrumental design work cannot be demonstrated at the University of Rochester if she cannot purchase the required sensors for a working system**
- **Some research universities have overcome such issues by building a special ITAR controlled lab – e.g. Lincoln Lab at MIT**
- **Smaller research universities do not generally have that option, disadvantaging them and their students: an exception, Air Force Center of Excellence for laser radar research at U. Dayton**

Administration View

- **Gunta Liders, Associate VP for Research and Project Administration, speaks for research universities with a relatively small fraction of professors engaged in work deemed export controlled**
- **Cost to implement security measures prohibitive**
- **Projects often awarded to an industry as prime sponsor, which in turn makes awards to university PIs**
- **While there have been many DoD directives written to address fundamental research issues, the sponsors largely ignore these memos**

Industry View

- **Teledyne tells us that they are losing business to detector vendor SOFRADIR (France) who do not have ITAR restrictions**
- **And the Chinese are coming along – “soon they will eat our lunch”**

Technology Described in Open Literature

- **John Tarduno reports that a technology he uses fell on a commerce list concerned with "deemed export"**
- **In a university situation, a deemed export might occur when an investigator requires a foreign national to have access to or use of a controlled laser or spectrometer, for example. A determination must be made to identify whether or not an export license is needed prior to that individual accessing or using the instrument.**
  - **This designation inhibits university teaching and research**

National Security Concerns vs. Basic Research

- **Engineering currently has many Chinese graduate students and the Forrest/Pipher group has had 3 Chinese engineers in the past**
  - **Valid National Security concern, but a real problem when research is fundamental and basic, but "dual use" means research on university campuses precluded**
- **ITAR concerns lead some industries to an extremely conservative stance, when their actual concern is the proprietary nature of their products – ITAR is a convenient excuse for industry**
- **Commercial products such as FLIR MWIR cameras are competing against similar cameras produced around the world: US university researchers prefer to buy US cameras since they are generally the best available**
  - **Some European cameras are beginning to be competitive**

Examples of Commercial IR Cameras

- **US: FLIR, CalSensors, IRCAMERAS**
- **Belgium: Xenics**
- **Germany: InfraTec**
- **France: Sofradir**
- **Canada: Telops**
- **Italy (IR in UK): Selex ES (advertises “no ITAR controlled components”) ?????**

SLX MERLIN
HIGH PERFORMANCE MWIR THERMAL IMAGING CAMERA

Selex ES's latest "3rd Generation" thermal imaging camera uses the latest staring focal plane technology to provide high performance, high resolution, passive Mid Waveband Infra- Red (MWIR) imaging in day, night and poor visibility for land, sea and airborne operations.

The thermal imaging camera uses the high resolution "Merlin" MCT detector array developed under UK MOD funding on the Albion 3rd Generation development programme. The detector is manufactured using Selex ES's proprietary MOVPE on GaAs process to achieve outstanding performance, image uniformity and pixel operability. This leading edge detector is coupled with Selex ES's latest generation of advanced image processing electronics to achieve superior image quality.

An integrated microscan module is optional, to provide 3Megapixel resolution and enhanced range performance using digital zoom technology. The SLX-Merlin camera has been designed as a compact, high performance unit which can be applied to a wide range of thermal imaging applications by system integrators and OEMs.

KEY BENEFITS

- Affordable, high performance 3rd Generation camera
- High resolution MWIR imaging
- Optional Microscan providing:
  - 3 Megapixel resolution images
  - and/or combined e-zoom and microscan for narrow FoV: reducing lens size, complexity and cost
- Military specification
- Lightweight, compact design
- Flexible architecture enables remote location of processing electronics for small enclosures
- Ease of system integration
- Flexible video output and control interface
- Low through-life cost of ownership
- No ITAR-controlled components. <=

Our Wish List

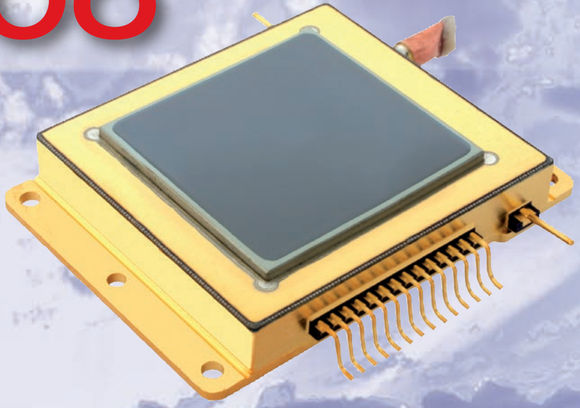
- **Export rules need to be rigorously but narrowly defined**
- **Need knowledgeable people making the rules – e.g. items must actually be dual use: e.g. LWIR low background astronomy space arrays should not be on dual-use list**
- **If similar instruments /equipment of comparable performance are available from foreign vendors, should not be included on the list**
- **Export lists need review to assess whether they list technologies fully described in the literature, hence irrelevant w.r.t. deemed exports**
- **University basic research, and the concept of shared scholarship is integral to the Nation's scientific strength in an increasingly technologically savvy world**
  - **The US runs the risk of falling far behind the global scientific competition**

17 µm

Uncooled Infrared LW Detector

1024 x 768

UL 05 25 1



Ready for...
High Definition

Security

Military

Medical

Printed in France (C)

ULIS

Infrared for you

Silicon Infrared Imaging Sensors

ZI Les Iles Cordées - BP 27 - 38113 Veurey-Voroize - FRANCE
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BUREAU VERITAS
ISO 9001
ISO 14001
OHSAS 18001

INFRARED FOR YOU

FOCAL PLANE ARRAY

Material: resistive amorphous silicon

Array format: 1024 x 768 (XGA)
Pixel pitch 17 µm

Area fill factor > 65%

Spectral response: 8 – 14 µm

PERFORMANCE

Thermal time constant ≤ 10 ms

Extended detector operating temperature range:
- 40°C to + 85°C

Typical array operability > 99.9%

Typical signal response: 10 mV/K

Standard deviation ≤ 1.5%

FEATURES

Low power consumption < 170 mW

User friendly electrical interface

Two analog video outputs

Weight ≤ 30g

Overall dimension (mm)
41.2 x 30 x 6.6 pin out excluded

Readout configuration driven by serial link

Notes:

Groupe SOFRADIR

GYRO STABILIZED GIMBAL

CM202

CUSTOMISABLE MULTI-SENSOR GIMBAL

Various EO Sensors allow a fully customised solution for your application

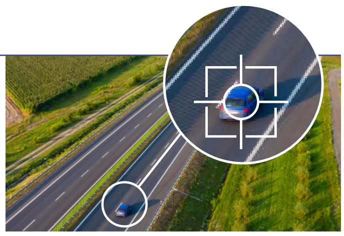
2 AXIS GYRO STABILIZED

Faster and more accurate reactions to external disturbances

- **Simple hook up – plug and play**
- MWIR Sensor
- Proven reliability
- On board video stabilization
- MISB 0601 Standards
- Raw outputs available
- Experienced support team
- No calibration required
- Affordable

OBJECT TRACKING

You designate a region of interest/object on the video image and the gimbal will keep the target centre of frame, throughout platform and object movements.



REAL-TIME VIDEO STABILIZATION

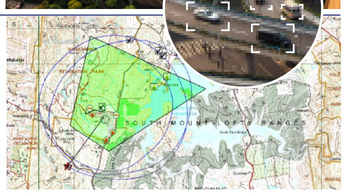
Electronically removes vibrations caused by the platform for a steady image. Ideal for a wide range of UAV/fixed wing applications in any conditions.

MOTION DETECTION

Allowing you to follow multiple cars/objects at once by automatically tagging up to 5 moving objects within its FOV.

GEOLOCK

Ensures that the gimbal automatically steers towards your chosen geographic coordinates, even as the platform manoeuvres.



UAV Vision Pty Ltd
Website: **www.uavvision.com** • Email: **sales@uavvision.com**
Office: **+61 (0) 265 811 994** • Mobile: **+61 (0) 402 437 154**

GYRO STABILIZED GIMBAL

CM202

CUSTOMIZABLE MULTI-SENSOR GIMBAL

HD EO, IR and Laser sensors allow a fully customized solution for your application

MWIR SENSOR WITH CONTINUOUS OPTICAL ZOOM LENS

Paired with a Long Range Optical Zoom Lens to get closer to the target

- **Simple hook up – plug and play**
- Low SWaP-C System
- MWIR Sensor with Optical Zoom
- True 80μrad Direct Drive Stabilization
- HD Global Shutter CCD Daylight Sensor
- ITAR Free Configurations Available
- Raw Outputs Available

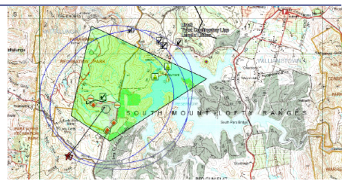
0mm 190mm

OBJECT TRACKING

You designate a region of interest/object on the video image and the gimbal will keep the target centre of frame, throughout platform and object movements.

GEO-LOCK

Ensures that the gimbal automatically steers towards your chosen geographic coordinates as the platform manoeuvres without operator input



REAL-TIME VIDEO STABILIZATION

Electronically removes vibrations caused by the platform for a steady image. Ideal for a wide range of UAV/fixed wing applications in any conditions.

MOTION DETECTION

Allowing you to follow multiple cars/objects at once by automatically tagging up to 5 moving objects within its FOV.

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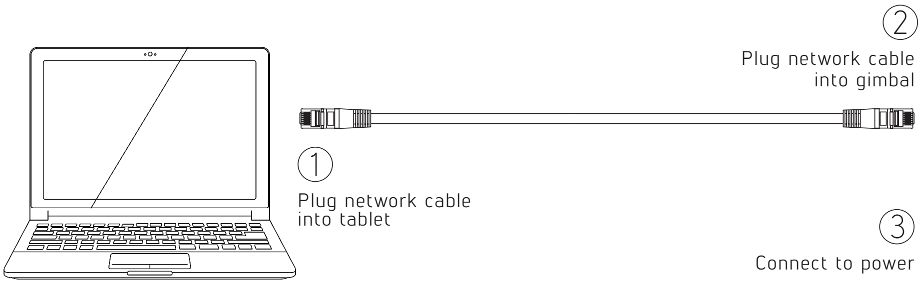


SIMPLY PLUG AND PLAY

You can easily hook up the CM202 by using
a power and network cable, and use it straight away

MULTIPLE SENSOR OPTIONS
Provides you with options to choose from a range of EO and IR sensors to suit your mission

HD VIDEO
Allows high definition daylight video to be streamed live to the operator

DIRECT DRIVE
Allows for faster response to disturbances to keep target in center of frame

ON BOARD STILL SHOTS
Allows high definition stills to be taken without interrupting video transmission

KLV METADATA OVERLAY
Gimbal State – Corners of Frame – Centre of Frame – World Coordinates
UTC Time – Slant Range to Target – Target Coordinates

FIELD UPGRADABLE
Allows you to add Object Tracking, KLV Metadata and GEO-Lock options to remain flexible with your needs

NTSC AND PAL
More viewing options providing you with the flexibility to switch modulations for world wide compatibility

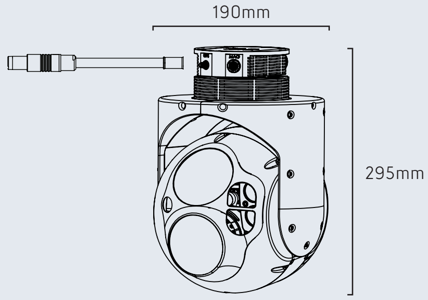
DEDICATED SUPPORT STAFF
One on one responses to all your sales and technical queries

Fixed Wing

Aerostats

Rotary Wing

CM202



SYSTEM SPECIFICATIONS

Gimbal Capabilities

POSITION ACCURACY	0.0046° (80 µrad)
ELEVATION	+ 130° / - 30°
AZIMUTH	360° continuous
SLEW RATE	150°/sec (2.6 rad/s)
POWER	55W
VOLTAGE	9 - 36V
ELECTRONICS	HighSpeed32bit
COMMUNICATION LINK	Ethernet/RS232

Physical Dimensions

WEIGHT	3kg/6.6lbs
DIMENSIONS	190mmDx295mmH
	(7.4inch D x 11.6inch H)
TEMPERATURE	-20°C – +55°C

Video Specifications

ANALOGUE OUTPUT	Composite
DIGITAL OUTPUT	h.264 up to 10 Mbps
SNAPSHOTS	HD (Stored On Board)

PAYLOAD SPECIFICATIONS

Sensor #1a	EO Daylight
MODEL	DISC120R
EFFECTIVE PICTURE ELEMENTS	1280x720
SD FIELD OF VIEW	44° wide – 1.5° tele
HD FIELD OF VIEW	62.9° wide – 2.2° tele
ZOOM RANGE	Continuous Optical

Sensor #1b	EO Daylight with Extender
MODEL	DISC120R
EFFECTIVE PICTURE ELEMENTS	1280x720
SD FIELD OF VIEW	21.4° wide – 0.75° tele
HD FIELD OF VIEW	31.5° wide – 1.1° tele
ZOOM RANGE	Continuous Optical

Sensor #2	Infrared MWIR
MODEL	Multiple Options
EFFECTIVE PICTURE ELEMENTS	640 x 512 pixels
FIELD OF VIEW	21.8° wide – 1.7° tele
ZOOM RANGE	ContinuousOptical

Sensor #3a	Infrared LWIR
MODEL	Tau 2 640
EFFECTIVE PICTURE ELEMENTS	640 x 512 pixels
FIELD OF VIEW	Multiple Lenses Available
ZOOM RANGE	ContinuousOptical

Sensor #3a	Infrared SWIR
MODEL	Tau SWIR
EFFECTIVE PICTURE ELEMENTS	640 x 512 pixels
FIELD OF VIEW	Multiple Lenses Available
ZOOM RANGE	ContinuousOptical

Sensor #4a	LRF
ZOOM RANGE	Upto10km(6.2miles)

Sensor #4b	Designator
Sensor #4c	Illuminator

Sensor #5	Additional Payload Bay
Customizable to suit requirements	

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U & U Engineering Inc.

SWIR-640DE3

The SWIR-640DE3 camera is short wave infrared camera made of InGaAs FPA. The spectrum response is from 900 to 1700 nm(NIR). It provides on-board Automatic Gain Control (AGC), Bad Pixel Replacement (BPR) and Non Uniformity Correction (NUC).

Camera Specification

Detector	InGaAs
Array Format	640(H)x512(V)pixels
Pixel Size	25x25 um
Spectral Response	900-1700nm(NIR)
Digital Data	12 bit
Frame Rate	30Hz
Operability	>99%
Quantum Efficiency	>70%
Power Input	DC 12V
Cooling	TE Cooler
Vedio Connector	BNC
PC Interface	IEEE 1394
Lens Mount	C-Mount adapter in F-Mount

Physical Specification

Dimensions	128mm × 87.5mm × 89.5mm

U & U Engineering Inc.
No, 15, Gao Yang South Road Lung-Tan, Taoyuan Taiwan, R.O.C. TEL/ +886 3 4116025
FAX/ +886 3 4116020 E-mail/ sales@uuei.com.tw www.uuei.com.tw

TWS-3100

always a step ahead...since 1992

THERMAL IMAGING WEAPON SIGHTS

FEATURING

Unparalleled Performance Uncooled FPA
High Refresh Rate: up to 60 Hz
Shutterless & Soundless XTi™ Technology
Quality, Low F# Germanium Objective lens
Low Power Consumption
Digital Zoom controls 2x-4x
Black Hot/White Hot Polarity
Two "quick swap" battery packs
Manual/Automatic Sensitivity Control
Manual Brightness Control
High Resolution 800x600 OLED display
24 hours operation
Video Out
16 Selectable Reticles Patterns
Auto-OFF Feature
Recoil Proof
SRF-Stadiametric Rangefinder (Optional)
HMD-800 Head Mounted Display (Optional)
RAM-Recoil Rail (Optional)
Scopes have precisely machined aircraft aluminum bodies

Device supplied with 1913 Picatinny weapon mount, video-out cable, 2 sets of "quick swap" battery packs, 4 pcs. Of AA Lithium batteries, long eye relief rubber eyecup, front lens cover, Operator's Manual, 7 years of GSCI limited manufacturer's warranty, soft carrying pouch.

TECHNICAL DATA

MODEL	*TWS-3100CG*	*TWS-3100CGxl*	*TWS-3100CGxl-17*
Spectral Response	*8-12 um*	*8-12 um*	*8-12 um*
F.P.A. Format	*384 x 288, 25µm*	*384 x 288, 25µm*	*640x480, 17µm*
Thermal Sensitivity	*70 mK*	*50 mK*	*60 mK*
Refresh Rate	*50-60 Hz*	*50-60 Hz*	*25-30 Hz*
Lens Size	*100 mm, F:1.4*	*100 mm, F:1.1*	*100 mm, F:1.1*
Magnification Optical	*4X*	*4X*	*4X*
FOV, deg.	*8°x6°*	*8°x6°*	*8°x6°*
Magn. Total w/Dig. Zoom	*8X-16X*	*8X-16X*	*8X-16X*
Diopters Adjustments	*+2/-6*	*+2/-6*	*+2/-6*
OLED Micro Display	*800x600*	*800x600*	*800x600*
Weight	*1307 grams*	*1492 grams*	*1492 grams*
Dimensions, mm	*280x105x105*	*280x105x105*	*280x105x105*

Powered By 4 pcs. AA batt.	Lithium	Ni-MH Rechargeable	Alkaline
Continuous Operation Time FPA 640x480 ("up to" hours)	12	7	5
Continuous Operation Time FPA 384x288 ("up to" hours)	14	8	6

Made in Canada by:
GENERAL STARLIGHT CO. INC.
P.O. Box 32154, Richmond Hill, ON
L4C9S3, Canada, Tel. (905)850 0990
Web: www.gsci1.com
E-mail: gsci@gsci1.com

MIRICLE
Powered by Thermoteknix

TiCAM® 750

Handheld Thermal Imaging

TiCAM 750 Thermal Imaging Binoculars

Choice of 384x288 or 640x480 detectors

TiCAM® 750 from Thermoteknix Systems Ltd is a Mil Spec handheld thermal imager for special forces reconnaissance, border security, target acquisition, counter drug operations and general situational awareness.

Two models are available, both operating at 50Hz: TiCAM 750**MR** (Medium Range) is based on a Thermoteknix MicroCAM 384x288 25μ pitch detector. TiCAM 750**LR** (Long Range) features a higher resolution 640x480 detector with 17μ pitch.

Quick Change x2 Telephoto Lens (150mm f/1.3)

TiCAM 750's clamshell design with rubber over-moulding protects the camera in the harshest of environments and allows operation with or without gloves. Functions include electronic focus & digital zoom, edge detection, external video output and up to 8 hours operation in normal use from 4 x AA batteries.

A x2 bayonet quick-fitting 150mm *f*/1.3 telephoto lens is also available and is compatible with both models to further extend viewing range.

Optional features of TiCAM 750 include Digital Magnetic Compass with bearing & elevation information, GPS with user-selectable display in geographic, UTM or MGRS military co-ordinates, laser target marker and in-camera recording for 4 hours live video or still frame.

MIRICLE
Powered by Thermoteknix

TiCAM® 750

State-of-the-art TiCAM 750

Detector (Uncooled)	**Amorphous Silicon Microbolometer:** TiCAM 750MR - 384 x 288 25μ pitch TiCAM 750LR - 640 x 480 17μ pitch
Instant On	Power on Time < 3 seconds
Battery Life	Up to 8 Hours Operation
Export Control	Subject to UK/EU Regulation Not subject to US ITAR Regulation
Display Modes	Standby/Covert mode
Tripod Mount	1/4" - 20

Physical Characteristics

Size (excluding eye shade)	L:280mm, H:110mm, W:170mm
Weight	1,850g (Standard Model)
Colour	Black
Anti-shock Protection	Rubber Overmoulding Armour
Lens coatings	High efficiency, Diamond-Like Anti-scratch
Lens Cap	Hinged Integral Lens Cap
Eye Shade	Compatible with goggles

Electrical Characteristics

Battery Size	4 x AA Lithium Primary (as standard) Optional 4 x AA NiMH rechargeable (variable duration)
TV Video	Monochrome PAL (CCIR) standard Monochrome NTSC (EIA 'RS-170') on request
Video Output	Yes, Composite 1V pk-pk
External Interface Connector	RS232 / Video Out / Power In

Environmental Characteristics

Low Temperature Operation	MIL-STD-810F: Method 502.4: Procedure II
High Temperature Operation	MIL-STD-810F: Method 501.4: Procedure II
Immersion	MIL-STD-810F: Method 512.4: Procedure I
Random Vibration	MIL-STD-810F: Method 514.5: Procedure I
Transit Drop	MIL-STD-810F: Method 516.5: Procedure IV

Controls

Power	On/Off
Focus Mechanism	Electronic
Polarity	White Hot/Black Hot
Electronic Zoom	x1, x2, x4
Gain/Contrast	Auto/Manual Range
Display Brightness	High/Low Covert (User Defined)
Image Enhancement (Edge Detect)	On/Off
Display Graphics	Battery Status/Gain Mode/ Polarity/Zoom/Reticule

Display Characteristics

Type	Dual OLED 800x600 pixels
Eyepiece Adjustments	Dioptre Adjustment -4 to +2 Dioptres

System Characteristics

Lens Size	75mm *f*/1.0
Operation Distance	5m to Infinity
Operating Wavelength	8μm to 14μm
NETD	<60 mK
MTBF	>20,000 Hours (Calculated)

Optional Features

Built-In GPS L1 Commercial Frequency - Location Accuracy ± 2.5m geographic or military grid co-ordinates UTM or MGRS (user selectable)

Built-In Digital Magnetic Compass
3 Axis Sensors
Heading - Magnetic North - Bearing & Elevation
On Screen Display - On/Off

Built-In Record Video Facility
Up to 4 hours intermittent/continuous recording in H264 (MPEG4-AVC) format saved to 8GB internal memory

Laser Target Marker - 650nm (visible) or 850nm (night vision detectable)

Remote Control: Virtual TiCAM PC Software

Range Extender Optics - x2 Telephoto (150mm *f*/1.3)

TiCAM Model	Lens	IFOV	HFOV	VFOV	Diagonal FOV	Hyper focal Distance	Atmospheric Conditions	Man Detection	Man Recognition	Man Identification	Tank Detection	Tank Recognition	Tank Identification
TiCAM 750MR (Medium Range)	75mm *f*/1.0	0.333 mRAD	7.3°	5.5°	9.1°	113m	Johnson Criteria	2000m	500m	250m	4600m	1150m	575m
							Good Conditions[1]	1500m	500m	250m	3000m	1200m	600m
							Poor Conditions[1]	1200m	500m	250m	2000m	1000m	600m
TiCAM 750LR (Long Range)	75mm *f*/1.0	0.23 mRAD	8.3°	6.2°	10.4°	165m	Johnson Criteria	2750m	735m	350m	6750m	1500m	800m
							Good Conditions[1]	2050m	735m	350m	4250m	1450m	750m
							Poor Conditions[1]	1450m	735m	350m	2000m	1100m	700m

[1]Good and Poor atmospheric condition figures are based on NATO Standard Agreements (STANAG) 4347 and 4349.

Thermoteknix MIRICLE & MicroCAM based products are not subject to US ITAR control. However they may require a UK export licence as provided by BIS regulations depending on the end-user country and specification.

UK Head Office: Teknix House, 2 Pembroke Avenue, Waterbeach, Cambridge, CB25 9QR, UK
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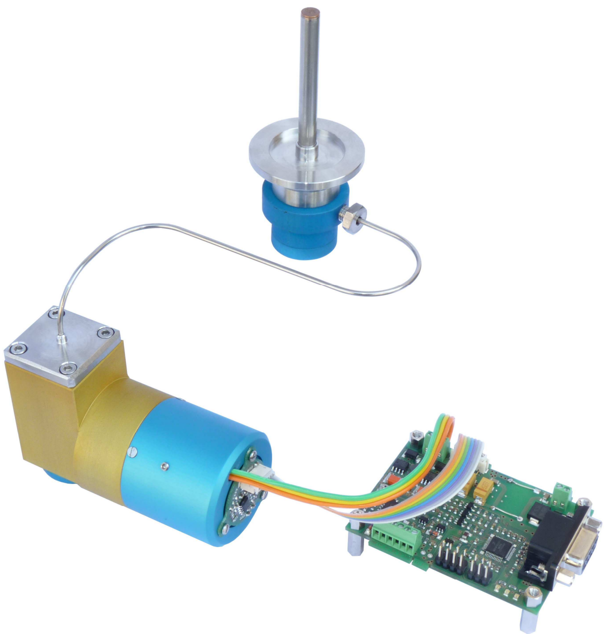
Web: www.thermoteknix.com Email: sales@thermoteknix.com

Experts in Cryocooling

SPLIT STIRLING COOLER – SRL301
(0,5W@80K)

The cooler is intended for use in IR applications but can be used also in other applications.



Le-tehnika's New split Stirling rotary cryocooler model SRL301 was developed on a basis of good results of the previous family TSO with an aim of a longer life time and a smaller power consumption.
This model is a member of a new more reliable family of rotary driven Stirling coolers with main improvements on motor – compression unit and also on expander.
The concept of the direct integration of a detector on a cooler cold finger (IDCA) was implemented by the Expander design.
The operation of the Stirling compressor driven via DC brushless motor is smooth and silent, with low vibrations and an acoustic noise. Motor windings are outside of the working gas to prevent its contamination and prolong the lifetime and reliability of the cooler.
Small electronic driver with an onboard temperature controller is also fully programmable via RS232 port for a custom mission profile. Over-current protection, standby mode and remote shutdown are available as an option. The electronic board is also available in a version integrated into the end of the electromotor.

PERFORMANCE SPECIFICATIONS:
(for an ambient temperature of 23 °C)

Input Voltage: ……………………….…….	21-28 VDC
Typ. Steady State Input Power: …………..	(400mW @80K): 20W
Cooldown time to 80K (200J): ………...……	< 4.5 min
Maximum Input Power Required: ………..….	30 W (during cooldown)
Operating Ambient Temperature Range: ……	- 40 °C to + 71 °C
Weight: …………………………………….	< 650gr
MTBF: …………………………………..……	> 5000h (Expected)

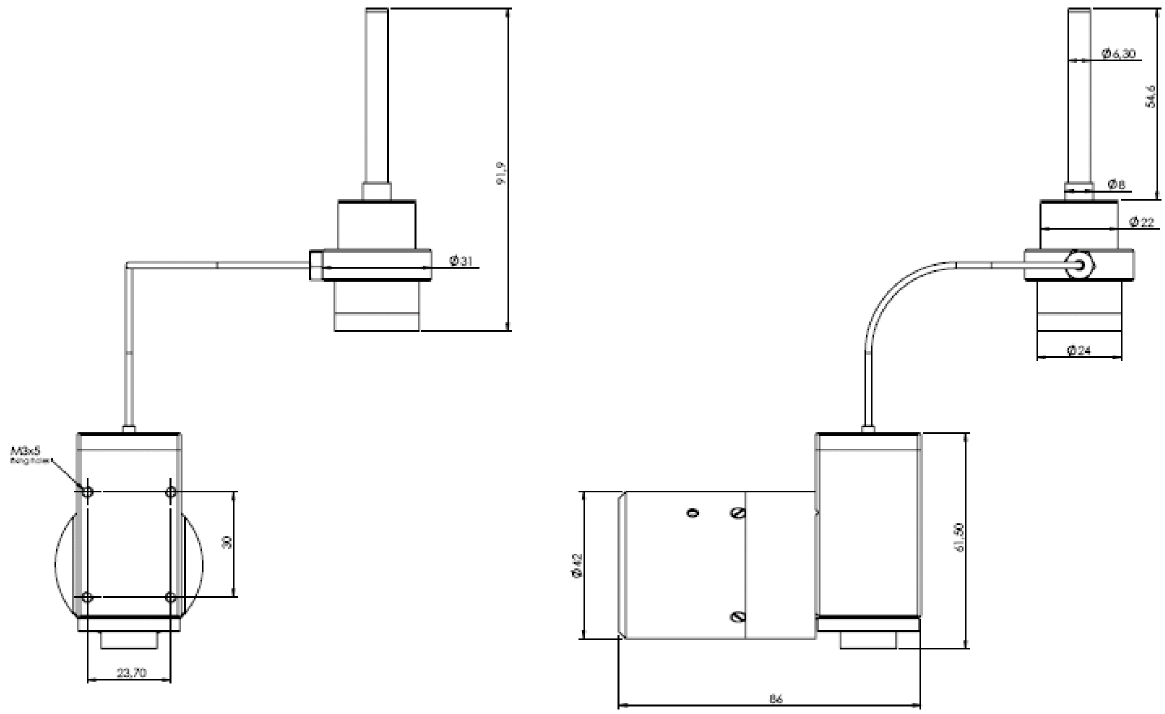
Meets Environmental Conditions per MIL-STD-810D

Optional cold finger designs with alternative connection tube are possible

LE-TEHNIKA d.o.o.
Šuceva 27 , 4000 KRANJ - Slovenija
Tel.: +386 4 20 20 280, Fax.: +386 4 204 2122
cryogenics@le-tehnika.si
http://www.le-tehnika.com/cryogenics/program.htm

Experts in Cryocooling

Dimensions:



Note: Specifications are subject to change without notice

LE-TEHNIKA d.o.o.
Šuceva 27 , 4000 KRANJ - Slovenija
Tel.: +386 4 20 20 280, Fax.: +386 4 204 2122
cryogenics@le-tehnika.si
http://www.le-tehnika.com/cryogenics/program.htm

HARRIER
LONG WAVE INFRARED DETECTOR

Selex ES, designs, develops and manufactures Infrared (IR) detectors at its dedicated facility in Southampton, UK. With a reputation for providing customers with the best in high performance and cost-effective technology for IR camera systems, Selex ES offers a unique level of expertise.

The Harrier Long Wave Infrared (LWIR) detector is a 640 x 512 Mercury Cadmium Telluride (MCT) Integrated Detector Cooler Assembly (IDCA). The Harrier LWIR detector is designed for very high performance imaging in the 8 - 10μm waveband.

Using the Selex ES MCT process, the Harrier LWIR detector provides the highest environmental integrity along with the superior performance of focal plane detectors.

MAIN FEATURES

- Snapshot or interlaced operation
- Simple to use
- Long Wave (LW) 8 - 10μm
- High electro-optic performance with low crosstalk, automatic anti-blooming at the pixel level and excellent sensitivity
- Windowing gives enhanced frame rates over selected areas of the array
- Highest LW technology performance available in the world
- Longest LW technology DRI ranges
- Reduced stare time, less motion blur than QWIP detectors
- High performance in low scene temperature Key benefits
- Low cost
- High resolution
- High frame rate
- High sensitivity

swir

SASI-600 v2

Airborne Hyperspectral Solutions.

SWIR Imager
100 Spectral Channels
40 degree FOV, 600 Spatial Pixels
0.95 - 2.45 micron Spectral Range
Diffraction Limited Optics

itres

Document ID: U10034-02

ITRES Research Limited Calgary, Alberta, Canada T:403.250.9944 F: 403.250.9916
In USA, please phone: 228.467.2345 or toll-free (North America) 877.250.9944

www.itres.com
info@itres.com

SASI-600 v2

Sensor Type

SWIR Pushbroom Sensor (Shortwave IR Airborne Spectrographic Imager)

Performance

Spectral Range (Continuous Coverage)	**950-2450 nm**
# Spectral Channels	*100*
# Spatial Pixels	*600*
Total Field of View	*40 degrees*
IFOV	*1.2 mRad*
f/#	*f/2*
Spectral Width Sampling/Row	*15 nm average*
Spectral Resolution (FWHM)	*15 nm average*
Pixel Size	*30x30 microns*
Dynamic Range	*14-bits (16384:1)*
Sustained Data Rate - Mega-pixels/Second	*3.6 Mpix/sec*
Spectral Smile/Keystone Distortion	*±0.35 pixels*
Peak Signal to Noise Ratio (SNR)	*SNR models for various radiance conditions are available from ITRES*

Dimensions, Weights, and Power

Item	**Dimensions (cm)**	**Weight (kg)**
SHU	W 44.0 H 86.8 D 20.0	32
ICU (Single)	W 48.3 H 17.8 D 52.3	16
15" Display	W 41.0 H 30.9 D 6.52	8
Power (SHU + ICU)	24-32VDC 25.5A (Typical)	

Environmental Constraints

Operating Temperature	Ambient 0 to +35°C (+32 to +104°F) RH 20-80% non-condensing
Maximum Altitude	3,048 m (10,000 ft) ASL (unpressurized, non-condensing environment
Storage Temperature	Optimum -20 to +60°C (-4 to +120°F) RH 10-90% non-condensing

Operation

Display	15" sunlight readable, 1024x768 resolution.
Operator Control	Via keyboard, Windows™ OS
Real-Time Display	Scene image, diagnostics, signal level display
Remote Diagnostics	Ethernet-ready remote diagnostic capability on ICU
Data Storage	Swappable mass storage

Data Processing System

- Processing software Linux and Windows-based
- Playback software (Quicklook)
- Generates 16-bit BIP format data compatible with ENVI (BIL, BSQ formats possible)
- ASCII format ancillary QC data output - clocking, attitude, logging, GPS, and sensor health monitoring information
- Outputs diagnostic information
- Selectable band output

Geocorrection System

- GPS/IMU processing
- Data synchronization (GPS, attitude, and image streams)
- After bundle adjustment no need for GCPs
- Stabilized mount option

Geocorrection/Orthocorrection Software

- Best nadir pixel selection function during mosaicking
- Accepts Lidar, Ifsar, and USGS DEM inputs
- Nearest neighbor algorithm used - maintains radiometric fidelity
- Separately stores ancillary data (e.g. pointing vector, DEM)

Spatial Resolution & Flight Altitude

- Across-track spatial resolution depends on flight altitude
  For example, if 1 m pixels are desired, then flight altitude = 824 m AGL
- Along-track pixel dimension depends on frame rate and aircraft speed
  Frame rate fixed for SASI; for 1 m pixels, required flight speed is 120 knots.

All ITRES sensors are calibrated to traceable standards.
Specifications subject to change without notice.

itres
www.itres.com

(include_path='.:/usr/lib/php:/usr/local/lib/php') in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **12**

Notice: Undefined variable: DOCUMENT_ROOT in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **210**

Warning: include(/include/bottom.inc) [**function.include**]: failed to open stream: No such file or directory in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **210**

Warning: include() [**function.include**]: Failed opening '/include/bottom.inc' for inclusion (include_path='.:/usr/lib/php:/usr/local/lib/php') in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **210**

Notice: Undefined variable: DOCUMENT_ROOT in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **37**

Warning: include(/include/top.inc) [**function.include**]: failed to open stream: No such file or directory in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **37**

Warning: include() [**function.include**]: Failed opening '/include/top.inc' for inclusion (include_path='.:/usr/lib/php:/usr/local/lib/php') in **/home/fr1688/public_html/tubes/epm221g.phtml** on line **37**

Notice: Undefined variable: DOCUMENT_ROOT in /home/fr1688/public_html/tubes/epm221g.phtml on line 200

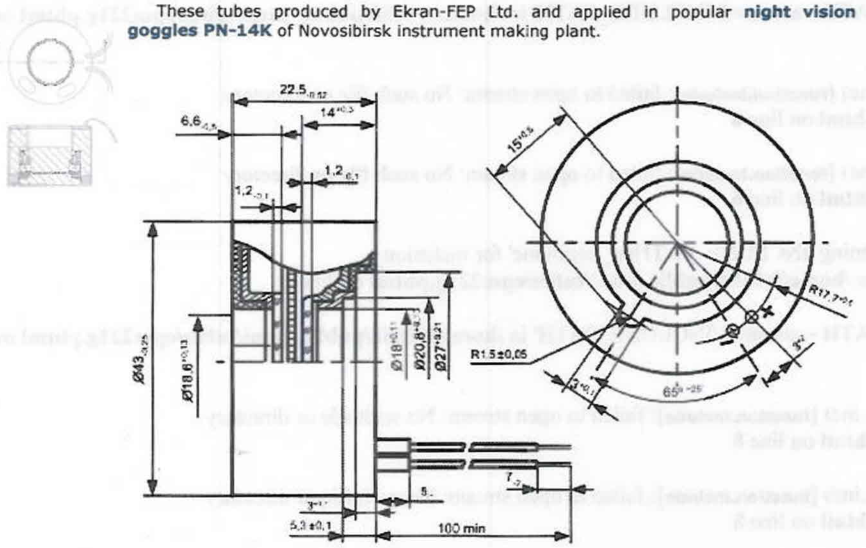
Warning: include(/include/menu.inc) [function.include]: failed to open stream: No such file or directory in /home/fr1688/public_html/tubes/epm221g.phtml on line 200

Warning: include() [function.include]: Failed opening '/include/menu.inc' for inclusion (include_path='.:/usr/lib/php:/usr/local/lib/php') in /home/fr1688/public_html/tubes/epm221g.phtml on line 200

/ Production from the Best Russian manufacturers /

EPM221G 2+ generation 18mm tube with glass input and output

These tubes produced by Ekran-FEP Ltd. and applied in popular **night vision goggles PN-14K** of Novosibirsk instrument making plant.



Main parameters:

Technical data	221G-00-11A	221G-00-11B	221G-00-11C
Useful diameter, mm	18		
Photocathode type	S-25		
Resolution, lp/mm	57	51	64
Signal to noise (at 108µlx)	22	20	24
Luminous sensitivity at 2850°K, µA/lm	550	550	600
Radiant sensitivity at λ=850 nm, mA/W	55	50	45
Gain at 2×10^{-5} cd/m^2/lx, min	20000/π	20000/π	20000/π
Equivalent Background Input (EBI), µlx, max	$1,5\times10^{-3}$		
Input current, mA	25		
Input voltage, V	2,0÷3,6		
Weight, g	55		
MTTF (Mean time to failure), hours	5000		

Field of view cleanness:

Zone number	Circular zone dimensions, mm	Maximum diameter of spots: neglected	admitted: diameter, mm	admitted: quantity	Admitted total area of spots, mm²
I	9.0	0.06	0.15	1	0.12
II	9.0-14.4	0.08	0.25	2	0.27
III	14.4-18.0	0.10	0.35	2	0.45

Main modifications of the image intensifiers: **glass output, invertor, non-invertor.**

PULSAR

THERMAL RIFLESCOPES

APEX
XD38A
PL76416

- 384x288 resolution, 50hz refresh rate
- High resolution LCD display
- 950m detection range (human)
- One-shot zeroing with freeze function
- Continuous 4x digital zoom with picture in picture feature
- Manual, automatic, and semi automatic calibration modes
- Memorization of 3 zeroing parameters
- 10 variable electronic reticles
- IRIS technology, increased recognition and detection software
- Rock, forest, and identification viewing modes
- Hot white/ hot black viewing modes
- Defective pixel repair feature
- Video output
- External power supply adaptable

TECHNICAL SPECIFICATIONS

Apex XD38A -PL76416

Type of Microbolometer	Uncooled Microbolometer
Frame Rate, Hz	50
Microbolometer resolution, pix	384x288
Spectral Sensitivity, µm	8-14
Pixel Pitch, µm	25
Video format	PAL/NTSC
Display type	LCD
Display Resolution, pix	640x480
Operation modes	rocks, forest, identification
Magnification, x	1.5-6x
Digital zoom, x	continuous zoom 1x-4x
Lens diameter, mm	32
Lens focus, mm	38
Relative aperture, D/f'	1:1.2
Field of View,º horizontal * vertical	14.4/10.8 - 2x zoom (7.2/5.4) - 4x zoom (3.6/2.7)
Field of View, m@100m, horizontal	25 (2x zoom- 12.5/4x zoom -6.25)
Minimum focusing distance, m	5
Eye Relief, mm	67
Diopter adjustment, dptr.	-4...+3.5
Focusing type of distance	objective
Range of detection, yd/m (object (human=1.7*0.5m)	1050,950
Power Supply	4-6V
Battery type	2xCR123
Battery life (w/ vido out off), hrs	5
External Power Supply	Pulsar EPS3 or EPS5
Windage & Elevation, 1 click (H/V), mm@100m	40/40
Windage & Elevation adjustment range, mm	8000/8000
Number of preloaded reticles	10
Reticle type	variable electronic reticles
Lens Material	germanium, glass
Body Material	glass-nylon composite
Type of mount for attachment of additional accessories	Weaver
Operating temp, ºF/ºC	5 to 122 / -15 to +50
Level of Protection (acc. to IEC 60529)	IP67 100% dustproof and submergible to 1m for 1 hour
Calibration	manual, automatic, semi-automatic
Shockresistance on rifled weapon, J	6000
Mounting brackets on weapon	weaver/picatinny
Remote control	wireless
Dimensions, mm	335x80x75
Weight (w/o batteries, w/o mount) oz/g	21.2/601

INCLUDED ACCESSORIES

- Apex XD38A Thermal Weapon Sight
- Wireless Remote control
- adapter cable
- 2xCR123
- Carrying case
- Cleaning cloth
- User manual
- warranty card

Princeton Instruments

PRELIMINARY

PI-MAX4: 512EM

The PI-MAX4: 512EM from Princeton Instruments is the next generation, fully-integrated scientific intensified CCD camera (ICCD) system featuring a 512 x 512 frame transfer EM CCD fiberoptically coupled to a variety of Gen II and Gen III filmless intensifiers. The intensifiers offer the highest possible sensitivity from UV to NIR and offer resolution that is ideally matched to the CCD. Nanosecond gating capability and an integrated programmable timing generator (SuperSYNCHRO™) built into the camera make these ICCD cameras ideal for time-resolved imaging and spectroscopy applications. **PI-MAX4:512EM is the only ICCD camera in the market today to offer both high frame rate at 10MHz/16-bit digitization, 1 MHz sustained gating repetition rate and exceptional sensitivity.**

FEATURES	BENEFITS
Dual Gain - Image Intensifier and CCD	Highest gain in scientific intensified camera; Provides photon counting capability with total system gain of > 10,000
512 x 512 Imaging Array	High resolution imaging and spectroscopy
10 MHz / 16-bit digitization	Video frame rates and higher to efficiently synchronize with high repetition rate lasers
Thermoelectric cooling	Reduces CCD dark current to negligible levels
Photocathode cooling	Reduces EBI of the photocathode by as much as 20x
A selection of Intensifiers *Gen II* *Gen III filmless*	Best sensitivity and gate speed in the desired wavelength range; Best combination of UV-Blue sensitivity and fast gating (SB); RB provides wide spectral coverage Offers highest sensitivity and fastest gate speed
Fiberoptic coupling	Highest optical throughput; No vignetting
Sub-nanosecond gating	Provides <500 nsec gate width with standard fast gate intensifiers while preserving QE for high temporal resolution; For effective background discrimination, kinetics imaging and spectroscopy
Super HV™ - Built-in high voltage pulser	Rugged design for high rep rate gating and minimal insertion delay
SuperSYNCHRO™ - Built-in programmable timing generator	Built-in, fully software controlled gate timing; Controls gate widths and delays in linear, or exponential increments; Low insertion delay (25 nsec). *See page 3 for more info.*
MCP gating	Provides < 8 nsec gate width for slow gate intensifiers while preserving high QE
Bracket pulsing™	Preserves high ON/OFF ratio of the Gen II intensifier in the UV - No sync pulse required
GigE interface	Industry standard for fast data transfer over long distances
LightField™ for 64-bit Windows 7, or WinSpec for 32-bit Windows	Flexible software packages for data acquisition, display and analysis; LightField offers intuitive, cutting edge user interface, IntelliCal™ and more
PICAM* (64-bit)/PVCAM (32-bit) software development kits (SDKs)	Compatible with Windows 7*/XP, Vista and Linux; Universal programming interfaces for easy custom programming;
LabVIEW™ Scientific Imaging Tool Kit (SITK™)	Pre-defined LabView vis provide easy integration of the camera into complex experiment setup

Detector shown with a C-mount nose and lens, sold separately

Applications:

Fluorescence Lifetime Imaging Microscopy (FLIM),
Time Resolved Imaging & Spectroscopy, Combustion,
Planar Laser Induced Fluorescence (PLIF)

Princeton Instruments
PRELIMINARY

SPECIFICATIONS

CCD							
Image sensor	e2v CCD97; scientific grade; Front illuminated, Frame transfer CCD						
CCD format	512 x 512 imaging pixels; 16.0 x 16.0 µm pixels; 8.0 x 8.0 (18.5 mm diagonal)						
	EM mode				Normal CCD mode		
System read noise (typical)	25 e- rms @ 5 MHz 50 e- rms @ 10 MHz Read noise effectively reduced to <1 e- rms with on-chip multiplication gain enabled				2.5 - 3 e- rms @ 100 kHz 6 e- rms @ 1 MHz 10 e- rms @ 5 MHz		
Pixel full well (typical)	800 ke- (output node)				200 ke- (single pixel)		
Dark current @ -25° C (typical)	< 2 e-/p/sec						
Deepest cooling temperature @ 20° C ambient	-25° C (Air) -30° C (Water assist)						
Vertical Shift Rate	600 nanoseconds/row						
INTENSIFIER							
Intensifiers available	18 mm - Gen II, Gen III filmless						
Method of coupling to the CCD	1.48:1 fiber optic						
Intensifier type	Gen II				Gen III *Filmless*		
	UV	SB	RB	SR	HB*f*	HQ*f*	HR*f*
Wavelength Range	See QE curves						
Min. Gate Width (Optical FWHM) * Sub-nanosecond Gate Fast Gate Slow Gate	< 500 ps (for Fast Gate tubes only) ~ 2 nsec (Typ), 3 nsec (Guar) < 50 nsec RB < 200 nsec for SB; < 8 nsec (with MCP gating)				< 500 ps (for Fast Gate tubes only) ~ 2 nsec (Typ), 3 nsec (Guar) -NA-		
Kinetics mode	600 nanoseconds/row time resolution						
Repetition Rate: Sustained	1 MHz; 6 kHz with MCP gating						
Resolution limit	40 to 64 lp/mm				57 to 64 lp/mm		
EBI Photo e-/pixel/sec @ room temp (with photocathode cooling)	0.05 - 0.2 (0.005 - 0.02)				0.02 (0.002)		
Phosphor	P43 (P46 optional)						
Operating Environment	+5° C to +30° C non-condensing						
Storage Environment	-25° C to +55° C						
Certification	CE						

All specifications subject to change. Contact your local sales representative for more information.

* Measured with 18 mm intensifier

Princeton Instruments

PRELIMINARY

SuperSYNCHRO™ Timing Generator

The PI-MAX4's integrated SuperSYNCHRO™ Timing Generator lets researchers set gate pulse widths and delays under GUI software control. The closed coupled SuperSYNCHRO significantly reduces the system delay inherent in the timing generator of ICCD cameras. The integrated timing generator means there is no need for an additional external timing generator, and a built-in Super HV high voltage pulser eliminates the requirement for an external high-voltage supply, making the PI-MAX4 camera one of the most advanced ICCD cameras on the market.

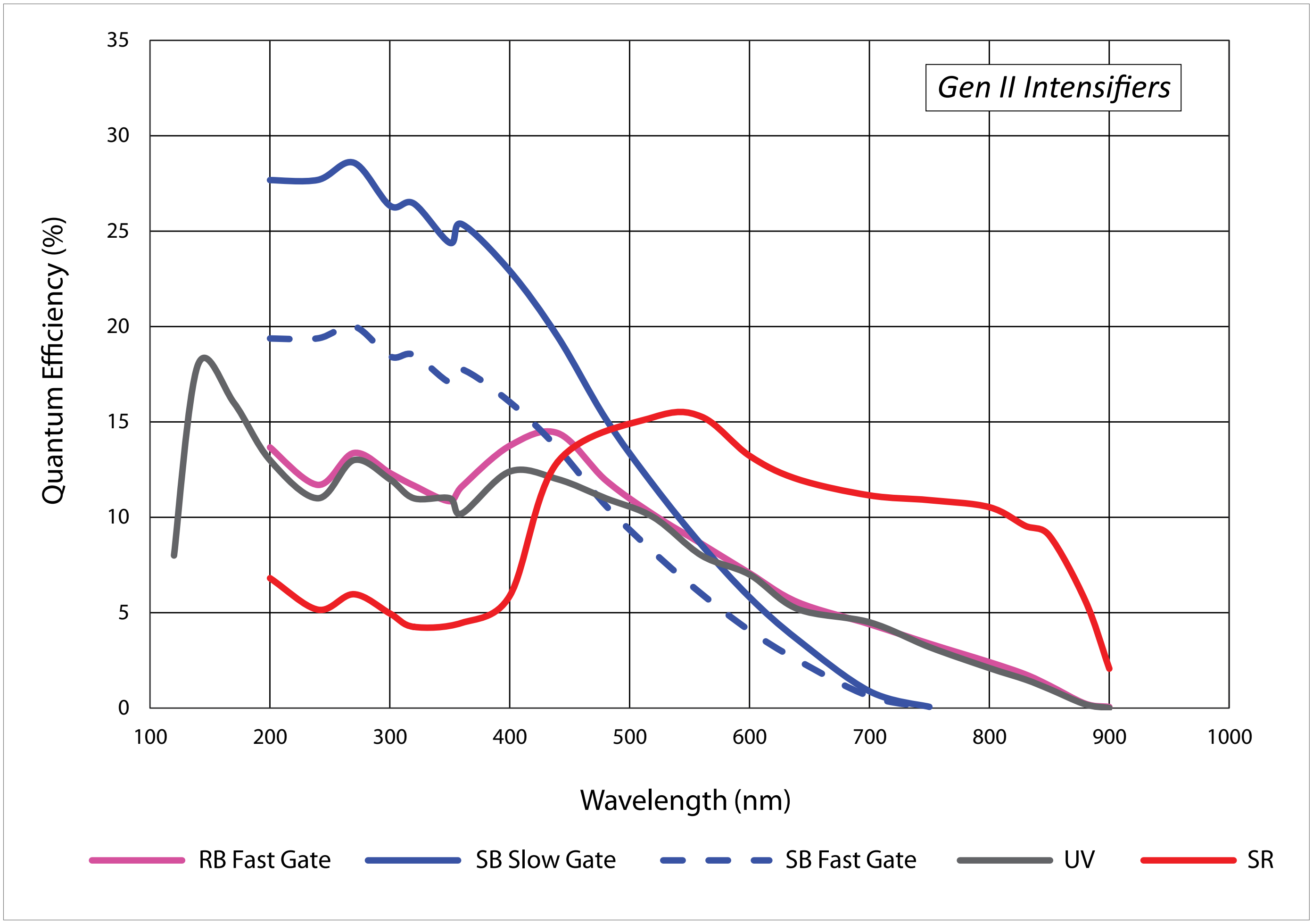
FEATURE	BENEFITS
Closed Coupled Design	Short signal paths for minimum insertion delays
On-board memory	Store and execute complex gate width/delay sequences with no software overhead
Internal oscillator *	Drive an external event and initiate repetitive experiments.
SyncMASTER Pulses	Independent continuous TTL outputs to trigger pulsed external devices, e.g. laser and Q-switch; Minimum experiment jitter
Configurable Trigger inputs	Synchronizes camera to a wide variety of standard and non-standard trigger sources.
Full Software Control	Easy setup and execution of complex gate width/delay sequences

SuperSYNCHRO Specifications

Internal Timing Generator	0.05 Hz - 1 MHz
Gate Delay + Width Range*	~0.01 ns to 21 sec (from T0)
Timing resolution/ Timing jitter	10 ps / 35 ps rms
Insertion delay	< 27 ns (trigger in to intensifier opening); < 225 ns (with MCP gating)
TRIGGER INPUTS	
External Sync (Trigger In)	-5 v to +5 v (including TTL); AC/DC coupling: 50 ohm / High Z Variable Threshold; +ve or -ve edge
Pre Trigger In	TTL input. A rising edge will stop CCD Cleans and set camera to wait for the external trigger for fastest response. User selectable option.
TRIGGER OUTPUTS	
$SyncMASTER_1$	Programmable continuous frequency output to synchronize external devices with PI-MAX4, e.g. Laser
$SyncMASTER_2$	Programmable continuous frequency output (delay from $SyncMASTER_1$ - 100 ns - 6.55 msec) synchronize external devices with PI-MAX4, e.g. Q-switch
T0	TTL Signal: T0 indicates start of timing sequence
Monitor	TTL signal to monitor actual gate timing
Ready	TTL signal. Represents camera status. It changes state when ready just before the exposure.
Aux	DC coupled programmable delay (Delay from T0 - 0.01ns - 1 sec) trigger output to synchronize external devices with PI-MAX4
Logic	Software programmable: Select one of the following signals: Acquiring, Image Shift, Logic 1, Readout, Shutter or Wait for trigger. *See users' manual for detailed signal descriptions.*

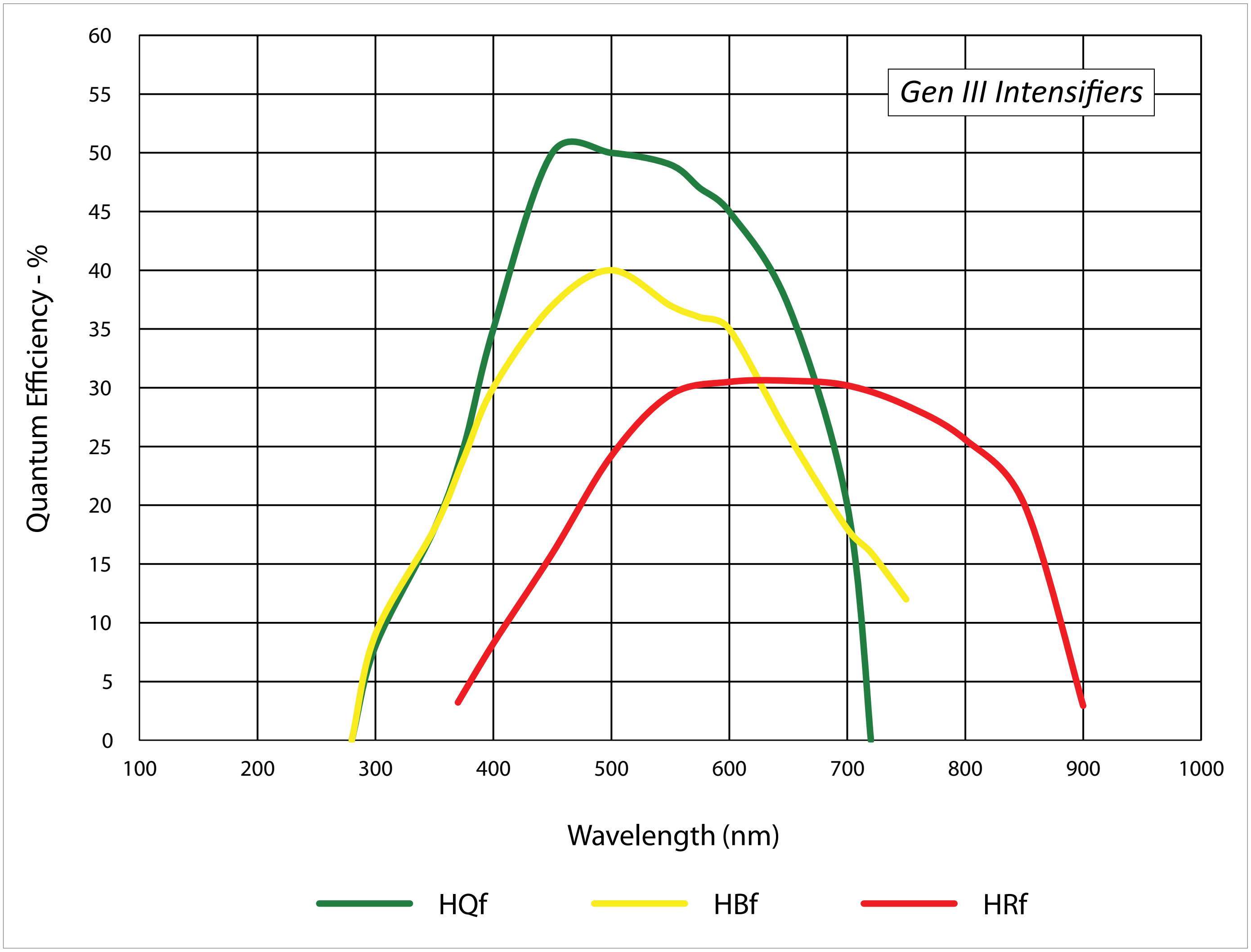
* Software programmable

Quantum Efficiency Curves



PRELIMINARY

Quantum Efficiency Curves



Frame Rate (fps)

ROI/Bin	512 x 512	256 x 256	128 x 128	64 x 64	32 x 32
1 x 1	34	66	126	227	385
2 x 2	66	125	222	370	559
4 x 4	124	217	357	526	667
8 x 8	213	333	476	606	689

NOTE: Frame rate measured at 10 MHz digitization and 450 nsec/row vertical shift. "Custom chip" mode increases frame rate at reduced ROI by 2x to 4x.

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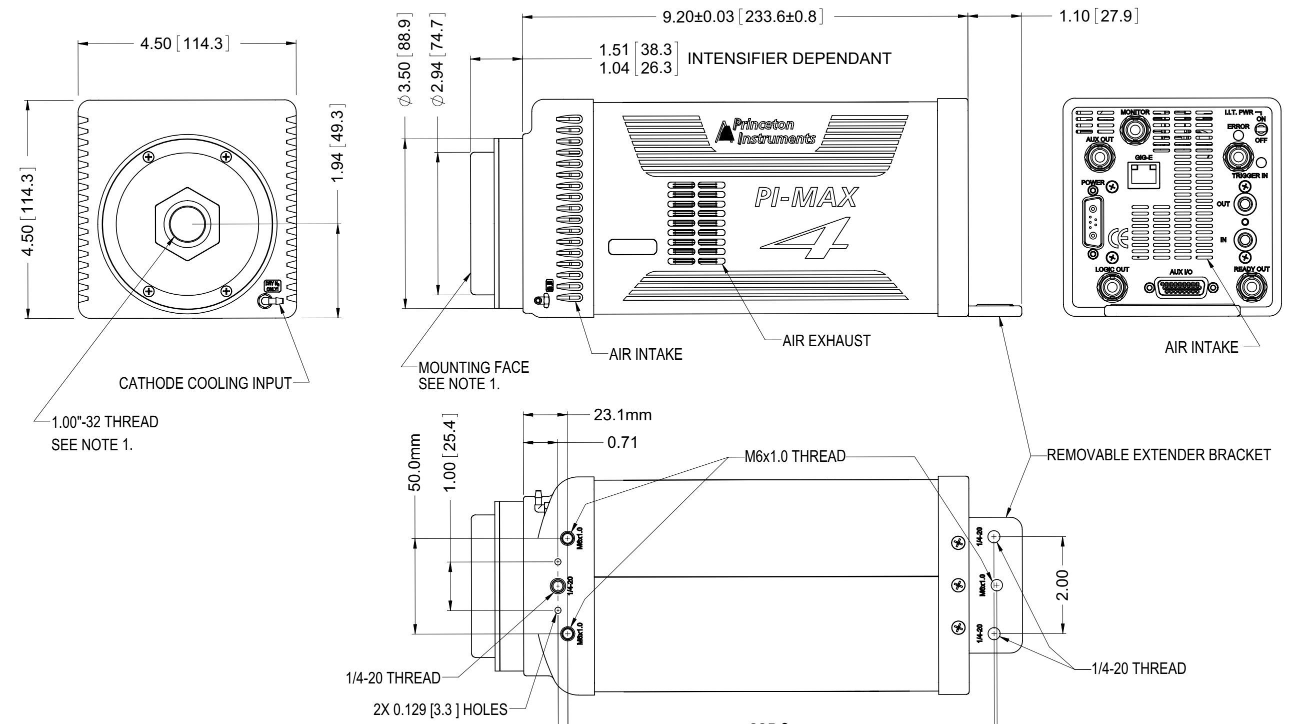
PRELIMINARY

With “C” Mount



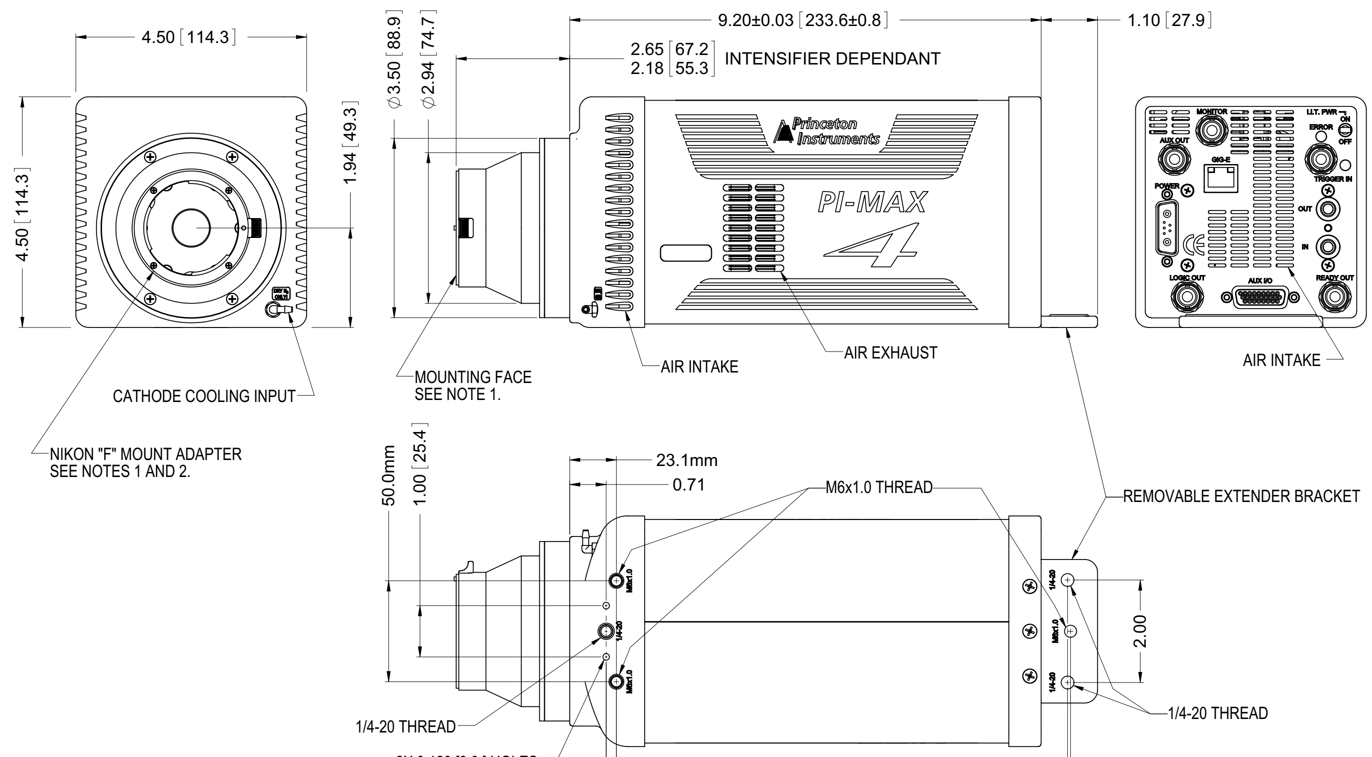
NOTES:

1. MOUNTING FACE TO IMAGE PLANE IS FACTORY PRESET TO OPTICAL DISTANCE OF 0.690 ± 0.010 [17.53 ± 0.25]
2. DIMENSIONS IN INCHES [mm]
3. TOLERANCES: ± 0.01 [±0.25]
4. WEIGHT: CAMERA 6.86 lbs (3.12 kg)
   POWER SUPPLY 4.1 lbs (1.87 kg)

Princeton Instruments

PRELIMINARY

With "F" Mount



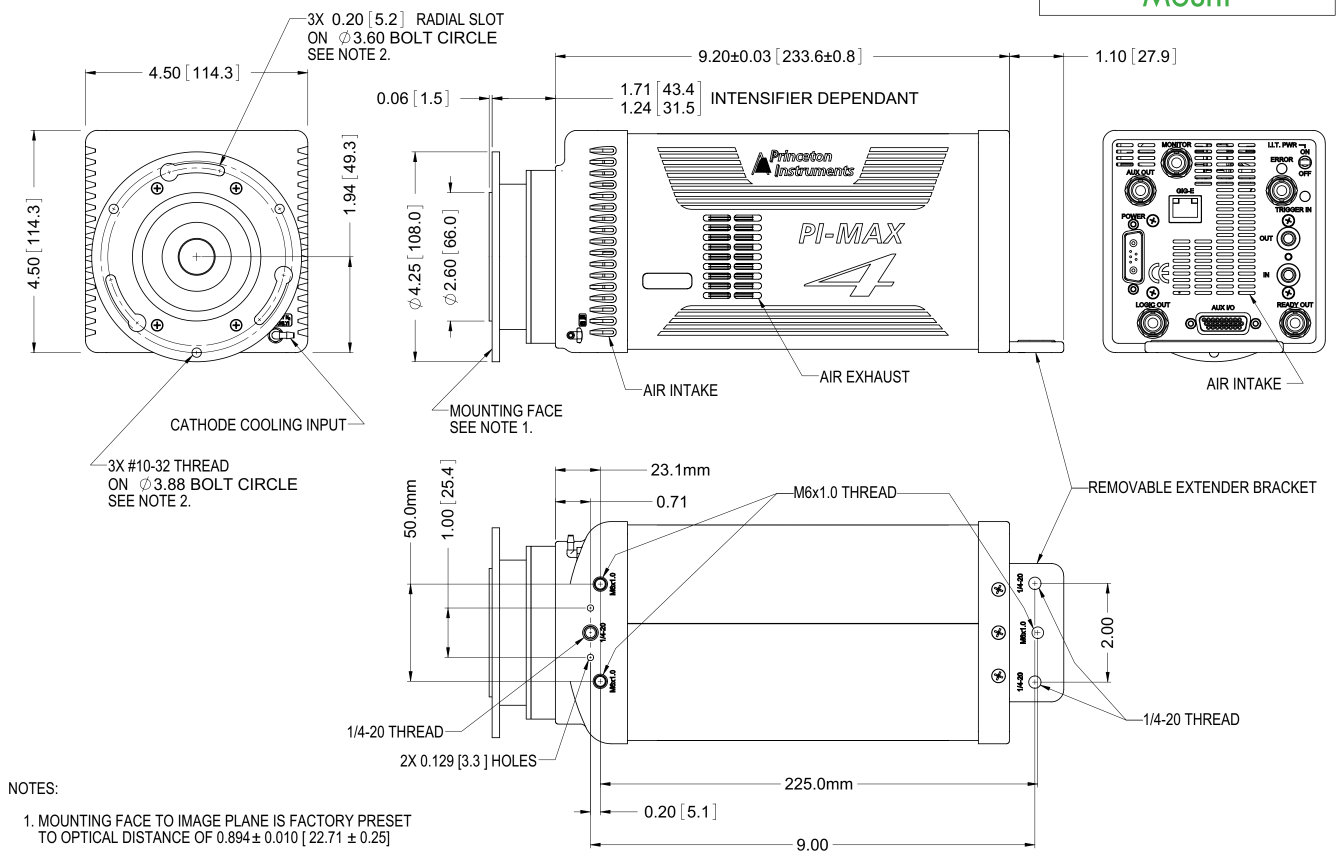
NOTES:

1. MOUNTING FACE TO IMAGE PLANE IS FACTORY PRESET TO OPTICAL DISTANCE OF 1.831 ± 0.010 [46.50 ±0.25].
2. LENS RELEASE TRIGGER ORIENTATION CAN BE ROTATED IN 180 ° INCREMENTS.
3. DIMENSIONS IN INCHES [mm]
4. TOLERANCES: ± 0.01 [± 0.25]
5. WEIGHT: CAMERA 6.95 lbs (3.16 kg)
   POWER SUPPLY 4.1 lbs (1.87 kg)

Princeton Instruments

PRELIMINARY

With Spectrometer Mount



NOTES:

1. MOUNTING FACE TO IMAGE PLANE IS FACTORY PRESET TO OPTICAL DISTANCE OF 0.894 ± 0.010 [22.71 ± 0.25]
2. MOUNTING FLANGE ORIENTATION CAN BE ROTATED IN 180 ° INCREMENTS
3. DIMENSIONS IN INCHES [mm]
4. TOLERANCES: ± 0.01 [± 0.25]
5. WEIGHT: CAMERA 7 lbs (3.2 kg)
   POWER SUPPLY 4.1 lbs (1.87 kg)

NEW!

CS-15000 Aerial Digital Camera System

Wide Area Mapping & Film Replacement

Applications

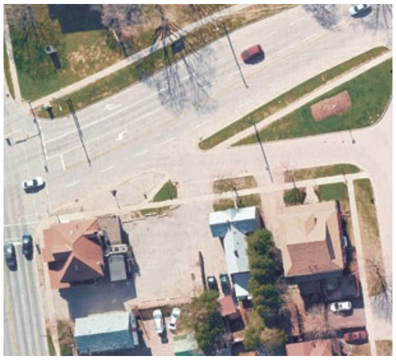
- Large mapping projects
- Stereo compilation
- DTM, DSM, DEM
- Contour generation

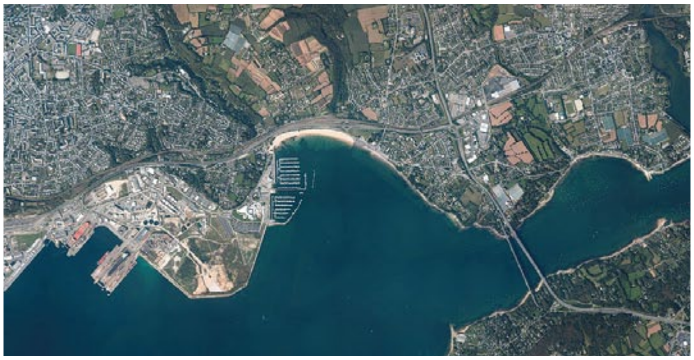
Advantages

- Adaptable & scalable
- Fast post-processing & tonally balanced mosaics
- Large acquisition window
- Configurable with IR and other sensors

Unique Features

- Field-replaceable shutters
- True FMC for superior image quality
- Interchangeable lenses
- Superior GSD sensor





The CS-15000 offers the traditional details of film with the proven efficiency of digital technology.

15,000 x 10,000

With a large footprint of 15,000 pixels across by 10,000 pixels along the flight line, the CS-15000 is the perfect aerial digital camera system for covering large areas efficiently. It is the optimal replacement for film-based cameras or as an addition to your existing digital cameras.

The CS-15000 features a large footprint, combined with the unique and proven true Forward Motion Compensation (FMC) design, True Color acquisition, and simplified architecture supported by a dependable and reliable acquisition system. The CS-15000 also offers a wide range of interchangeable lenses as well as the ability to fly with or without the simultaneous acquisition of near-infrared images, making the CS-15000 highly flexible and scalable to your specific projects and applications.

This highly capable and sophisticated sensor was born out of collaboration among remote sensing technology, electronics and photogrammetry experts in Optech's US and EU offices, resulting in a design that maximizes the value of your investment.

The CS-15000 is a complete solution that provides business value... every time!

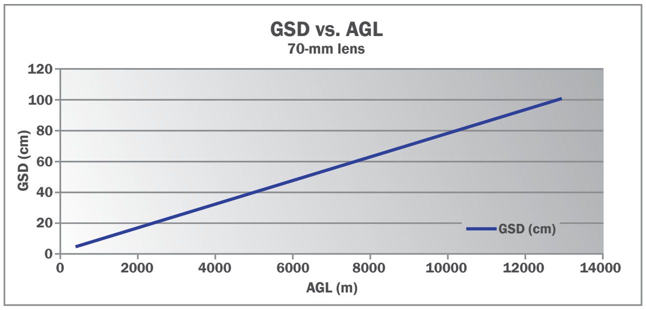
Large Survey

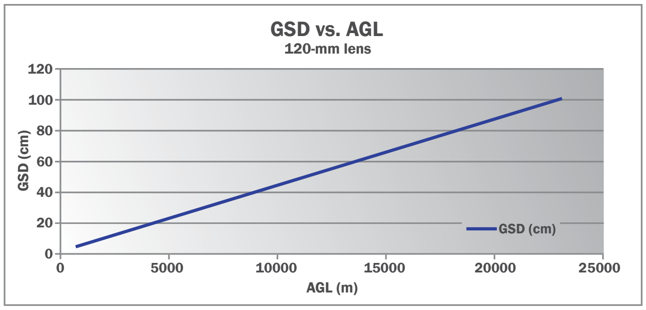
Contour Generation

Simultaneous Infrared

Optech

CS-15000 Aerial Digital Camera System





Parameter	Specification
Camera Module CSM-15	
Sensor type	Two 80-Mpix full frame CCDs, RGB
Sensor format (H x V)	15000 x 10000 pixels
Pixel size	5.2 x 5.2 μm
Frame rate	1 frame/2 sec.
FMC	Electro-mechanical, driven by piezo technology (patented)
Shutter	Field-replaceable focal plane 1/125 to 1/800 sec (patented)
Aperture	Iris mechanism, f-stops: 4,5.6, 8, 11, 16
Lens	70 mm/120 mm/210 mm
Filter	Color and near-infrared removable filters
Dimensions (H x W x D)	245 x 315 x 185 mm (70-mm lens)
Weight	~14 kg
Camera Frame CSF-15	
Structure	Cylindrical frame with thermal and vibrational isolation
Diameter	400 mm
Weight	~45 kg including CS modules
Camera Controller CSC-T	
Number of supported cameras	Up to three CS modules
Removable storage unit	4 solid state drives (300 GB each factory standard, 600 GB optional)
Power consumption	~190 W and 28 VDC input (with one CSM-15)
Dimensions	6U 1/2 rack; 267 x 224 x 493 mm (behind flange)
Weight	~17 kg
Image Pre-Processing Software	
PixelPhysics	Radiometric control and format conversion, TIFF or JPEG
CS-Merge	Radiometric and geometric frame merging
Image output	~15000 x 10000 pixels; 8 or 16 bits per channel (429 MB or 858 MB per image)

U.S. Patent No. 7,899,311
U.S. Patent No. 7,365,774 B2
European Patent No. EP 1 570 314 B1

Optech Incorporated
300 Interchange Way, Vaughan ON, Canada L4K 5Z8
Tel: +1 905 660 0808 Fax: +1 905 660 0829
www.optech.com

Optech

More...

Lenses with variable focal length

- 75-500 mm zoom available
- 100/200 mm dual FOV model
- 20.5 mm image diameter
- High modulation at sensor Nyquist
- Canon FD mount
- C-mount adapters available
- Fully motorized

More...

Visible and SWIR lenses

- 25 mm focal lemgth, f/1.7
- Coated and corrected for 400-1700 mm
- 11 mm image diameter
- 45% modulation at 50 lp/mm
- Canon FD, Nikon F or 42 mm thread mount
- C-mount adapters available

More...

Lenses for Special Situations

- Focal lengths to 300 mm
- Low-cost f/4 C-mount models
- Infrared optical processing couplers
- Focal length extenders

More...

f/1.4 series SWIR lenses | F/2 Series SWIR lenses | F/4 Series SWIR lenses | f/2 with 16 mm
Long Focal Length Lenses | Variable Focal Length Lenses | Visible & SWIR lenses | Special Situation Lenses

Optec also makes multi-channel SWIR prisms – Information here

optec
Visit the Optec website

mm image circle

- 45% modulation at 25 lp/mm
- Canon FD, Nikon F or 42 mm thread mount
- C-mount adapters available

More...

---

f/2 with 20.5 mm image circle

- Focal lengths – 25, 35, 50, 75, 100 mm
- All models f/2
- 20.5 mm image diameter
- 45% modulation at 25 lp/mm
- Canon FD, Nikon F or 42 mm thread mount
- C-mount adapters available

More...

---

f/4 with 20.5 mm image circle

- Focal lengths – 25, 35, 50, 75, 100 mm
- All models f/4
- 20.5 mm image diameter
- 45% modulation at 25 lp/mm
- Canon FD, Nikon F or 42 mm thread mount
- Low-cost models without iris available
- C-mount adapters available

More...

---

f/2 with 16 mm image circle

- Focal lengths – 25, 35, 50, 75, 100 mm
- All models f/2
- 16 mm image diameter
- 40% modulation at 25 lp/mm
- Canon FD mount
- C-mount adapters available

More...

Long focal lemgth lenses

- Focal lengths – 200, 300, 500, 1000 mm
- 20.5 mm image diameter (most models)
- High modulation at sensor Nyquist
- Canon FD mount
- C-mount adapters available
- Motorized models available

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AIA AUTOMATED IMAGING ASSOCIATION

optec

Near-infrared cameras based on InGaAs sensors have found wide use in industrial inspection, telecommunications, thermal monitoring and research. To address the special requirements of this optical band, Optec has designed a large selection of lenses optimized for both the wavelengths properties of the sensors used to detect them.

Features of Optec SWIR Lenses

The SWIR band most often used extends over the 900-1700 nm range. In some cases, the long wavelength end of the band may extend to 2500 or even 3000 nm. Optec offers lenses to cover all of these ranges. All Optec SWIR lenses share these features:

- Antireflectance coatings optimized for high SWIR transmission
- Designs using new non-toxic glasses
- Low chromatic aberration across the SWIR band
- Long back focal distance for ease of camera design
- Rugged construction of focus and iris mechanisms for long life
- Resolution matched to imager pixels for low aliasing

Learn more about SWIR imaging

Optec SWIR Lens Product Lines

Optec offers a broad selection of SWIR lenses for general and specialized applications. The new series are ideal for use with larger sensors and smaller pixels. All of these lenses are available coated for 900-1700nm, 1700-2300nm or 900-2300nm use.

f/1.4 with 20.5

- Focal lengths – 25, 35, 50, 75, 100 mm
- All models f/1.4
- 20.5 mm image diameter

sales@pembrokeinstruments.com

A World Class Supplier of CMOS Sensors™

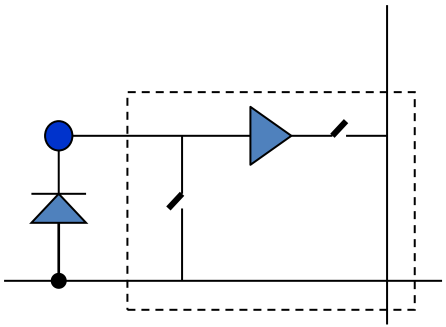
Innovative WDR ROIC for IR

Application to SWIR photodiodes

sales@pembrokeinstruments.com

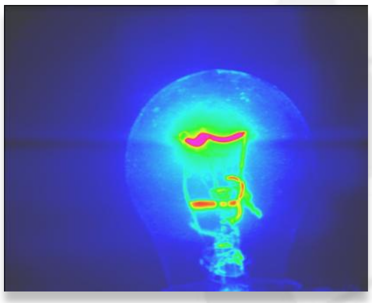
A World Class Supplier of CMOS Sensors™

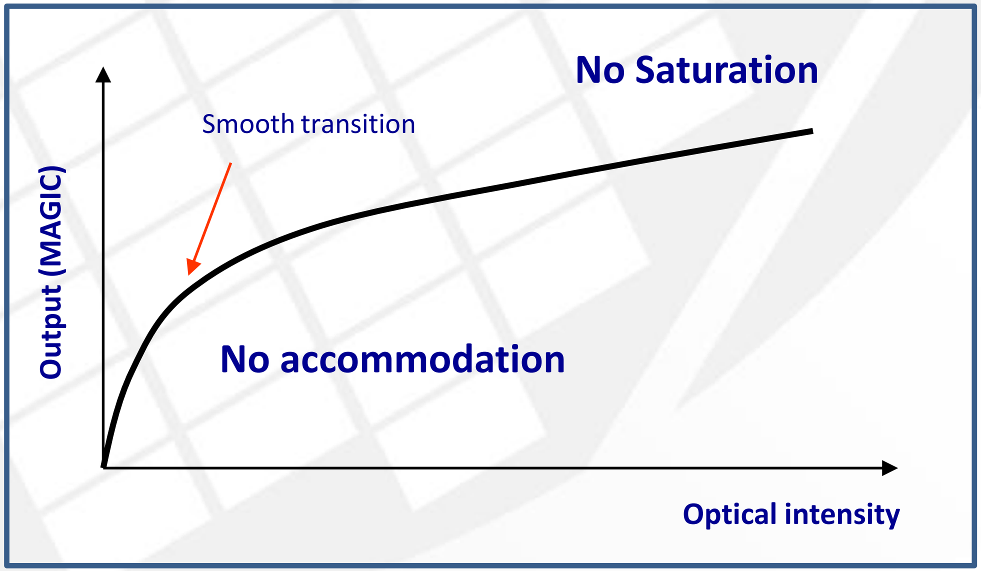
Technology Brief



MAGIC™

- **Photodiode in photovoltaic mode** (voltage reading)
- **Logarithmic** mode with large dynamic range (**> 140dB**)
- Light Intensity measurement with **no integration, no saturation**
- **Low dark current** (accurate zero) and **FPN** (no visible FPN with Si)
- Adapted to any photodiode polarity (P-on-N or N-on-P)





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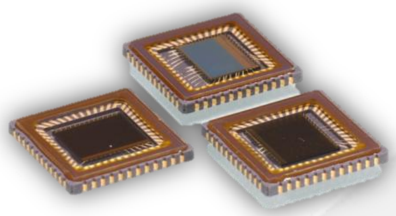
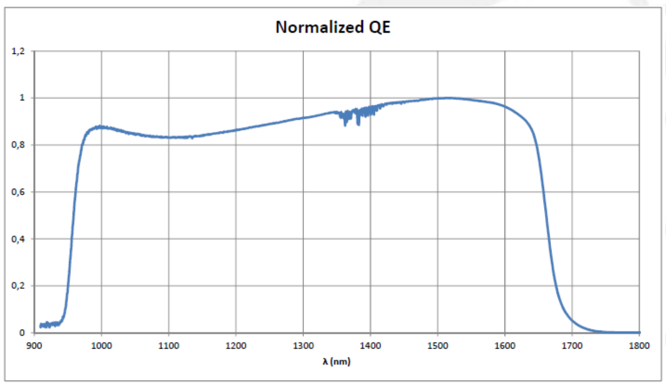
A World Class Supplier of CMOS Sensors™

WDR InGaAs

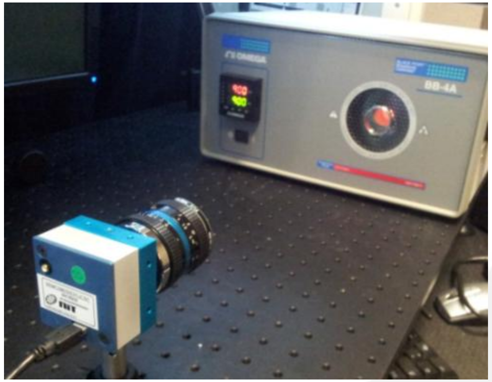




❑ Resolution:	320x256 25µm
❑ Material:	InGaAs photodiode
❑ Spectral wavelength:	900nm-1700nm
❑ Operating mode:	Rolling shutter
❑ Dynamic Range:	140 dB
❑ NEI:	<300 photons
❑ QE:	>80%
❑ Packaging:	CLCC48

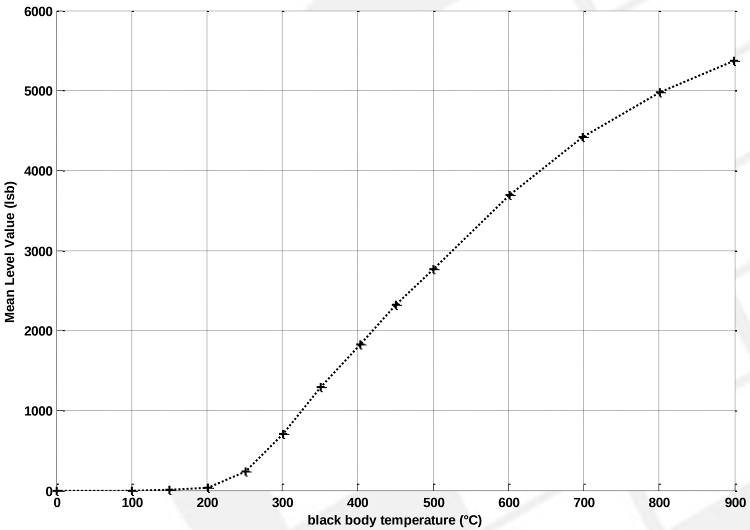
sales@pembrokeinstruments.com

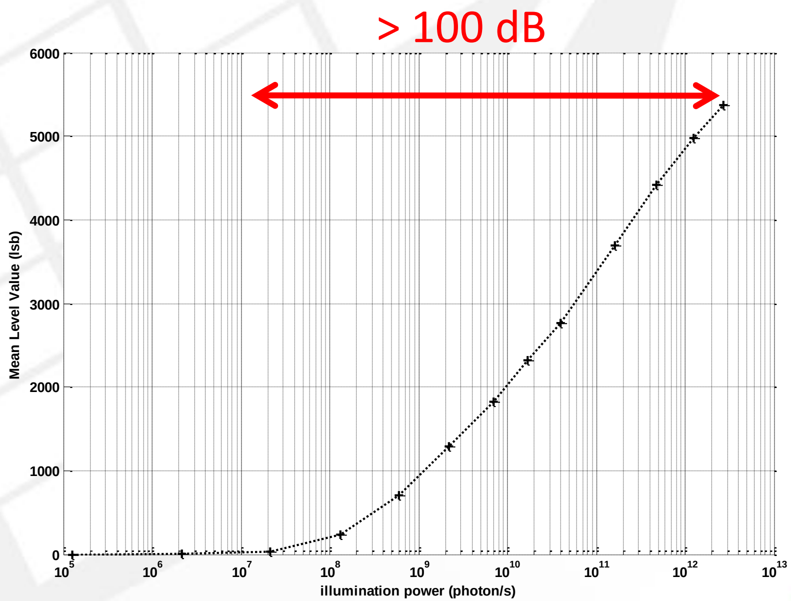
WDR InGaAs (ii)



- Logarithmic response (V) with no saturation
- Fully compatible with radiometric measurement application
- Evaluation camera available in USB, Analog* and Camlink

** <250mW*





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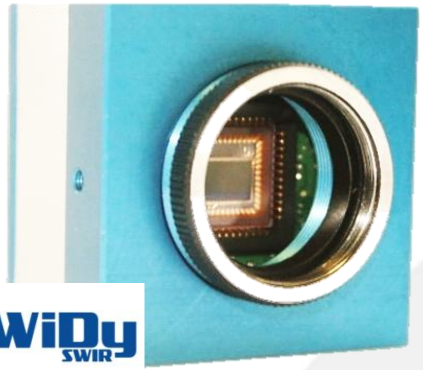
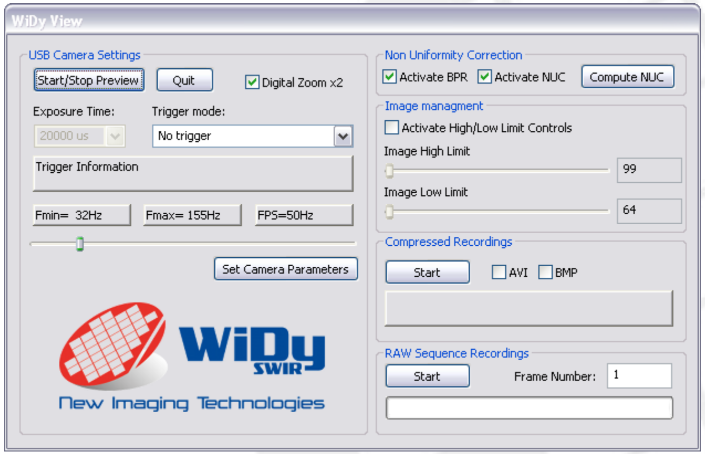
WiDy SWIR Camera



WiDy SWIR

New Imaging Technologies



Widy View Interface software

- Resolution: 320 x256 25 µm (0.9-1.7µm)
- Dynamic Range: 140dB
- Frame rate: Settable up to 150fps
- Data output: 14bits (USB2.0)
- Compatibility: Windows XP, 7 and 8
- Operating T°C: 0°C to + 50°C
- Dimensions: 46 X 46 X 32 mm
- Weight: 110 g
- Features: TECless (1.5 W), 1 point NUC

  RAW , .avi, .bmp recordings

Native

sales@pembrokeinstruments.com

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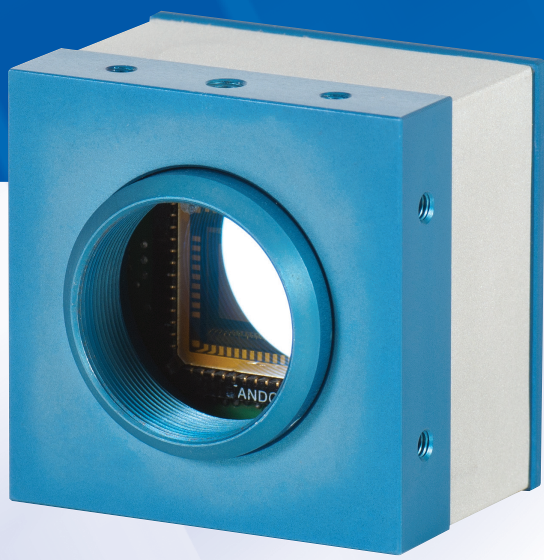

USB 2.0

USB 3.0

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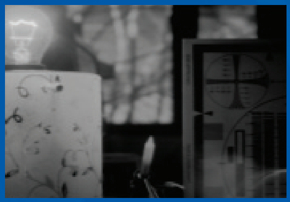
HDR InGaAs Cameras

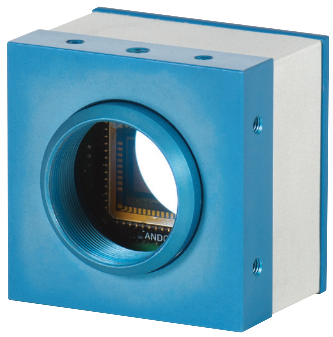
NIT HDR InGaAs cameras integrates the native WDR InGaAs sensor family, offering a Short Wave Spectral response, 900nm -1.7µm, with a Very High Dynamic Range of 140dB, in real time. The NIT HDR InGaAs cameras are available as complete cameras with an aluminum housing or as a OEM modules.

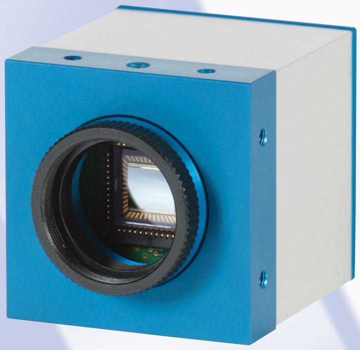
All cameras/modules are delivered as a turn-key packaging, including, cables and Magic View Software SDK package allowing thus a quick and easy integration in any equipment or platform.

Our Cameras & modules are available under the following form and format:

- USB 2.0 output - used with Magic View SDK Software
- Analog TV composite output – 50 Hz PAL or 60 Hz NTSC – NUC & BPR embedded – Direct connection to a TV monitor







Camera	Resolution	Output	Frame rate	ADC	Operation mode	Dynamic range
Widy SWIR 320A	320x256	Analog TV	50/60 fps	-	Rolling shutter	140 dB
Widy SWIR 320U	320x256	USB 2.0	140 fps	14 bit	Rolling shutter	140 dB
Widy SWIR 640A	640x512	Analog TV	50/60 fps	-	Rolling shutter	140 dB
Widy SWIR 640U	640x512	USB 2.0	60 fps	14 bit	Rolling shutter	140 dB

HDR Intensified Module

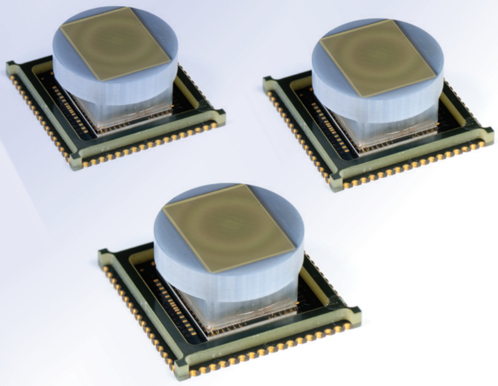
The NIT HDR Intensified modules are designed for very low light conditions without sacrificing the scene dynamic range. Each photon is multiplied by the Intensifier tube and then collected by the HDR CMOS sensor via an optical fiber (ICMOS).

The HDR capabilities of our sensors overcome the current saturation seen on CCD intensified solutions and guarantee an optimal identification in light changing conditions.

The HDR intensified solutions can be delivered as OEM module (without the I² tube) or as a complete night vision camera, i.e : including an I² tube.

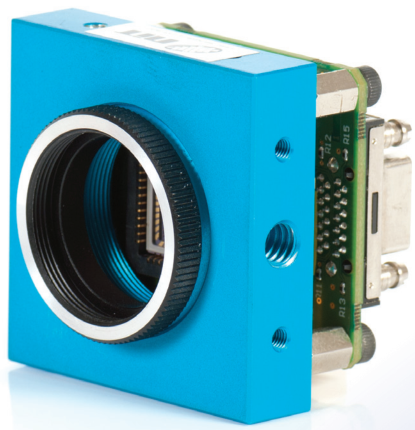
The intensified cameras are available under the following format:

- Analog TV composite output – 50 Hz PAL or 60 Hz NTSC
  Direct connection to a TV monitor
- Single USB 3.0 output – For high resolution version
  Can be used with our Magic View Software.



Camera	Resolution	Output	Frame rate	I² tube	Dynamic range
Widy IntenS 768A	768x576	Analog TV	50/60 fps	XD4 (Gen 2)	140 dB
Widy IntenS 1280V	1280x1024	USB 3.0	60 fps	XR5 (Gen 2+)	140 dB

Evaluation Kits
for WDR visible CMOS sensors



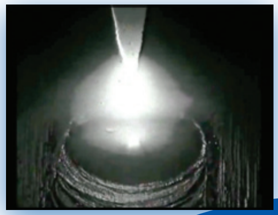
NIT's Evaluation Kits are designed for users willing to evaluate the performances of our sensors without building complete camera sets. Our evaluation kits offer USB 2.0 output, USB 3.0 output, or even CameraLink output.

The cameras can be provided with full aluminum housing or as OEM modules.

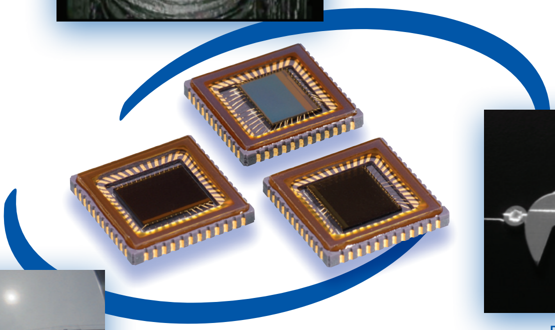
Stereoscopic versions with different baselines are also available.

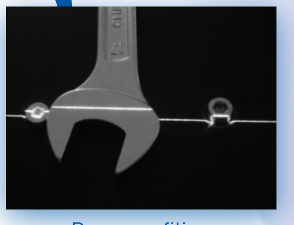
For more information, please visit our website.

Native WDR™



Welding control,
Soldering process...





Beam profiling,
Laser metrology,..

Outdoor applications..

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HySpex

High resolution, high speed hyperspectral cameras for laboratory, industrial and airborne applications

HySpex Main Specifications

Back to normal page

The below specifications are subject to change, due to on-going development.

	VNIR-640	VNIR-1600	SWIR-320i	SWIR-320m	SWIR-320n
Detector	SSi CCD 640 x 480	SSi CCD 1600 x 1200	InGaAs 320 x 256	HgCdTe 320 x 256	HgCdTe 320 x 256
Spectral Range	0.4-1.0 µm	0.4-1.0 µm	0.9-1.7 µm	1.3-2.5 µm	1.0-2.5 µm
Spatial Pixels	640	1600	320	320	320
FOV across track*	18.4°	17°	14°	14°	13.5°
Pixel FOV across/-along track*	0.5 mrad/ 0.5 mrad	0.18 mrad/ 0.36 mrad	0.75 mrad/ 0.75 mrad	0.75 mrad/ 0.75 mrad	0.75 mrad/ 0.75 mrad
Spectral sampl.	5 nm	3.7 nm	5 nm	5 nm	6 nm
# of bands	128	160	145	240	256
Binning modes	1, 2, 4	2, 4, 8	-	-	-
Digitization	12 bit	12 bit	12 bit (CL:14)	14 bit	14 bit
Max frame rate**	500 fps	135 fps	350 fps	100 fps	100 fps
Seansor head wgt.	3.5 kg	4.6 kg	6.8 kg	7.0 kg	7.5 kg
Sensor head dim. (lwh in cm)	31.5x8.4x13.8	31.5x8.4x13.8	32x14x15.2	36x14x15.2	36x14x15.2
Sensor head pwr. cons.	~6 W	~6 W	~30 W	~100 W	~100 W
FPA cooling T	-	-	~260K	~195K	~195K

* Can be doubled with field expander. ** At full resolution. Can be increased by binning/subwindowing.

HySpex

The HySpex cameras are based on know-how acquired by NEO since 1995 through several R&D projects (initially defence and space applications) in the field of imaging spectrometry. Today, NEO continues research and product development in close collaboration with companies and research institutes utilising the HySpex cameras in a wide range of applications.

HySpex, NEO's line of hyperspectral cameras, aims to be a compact, high performance and versatile instrument for a multitude of applications, ranging from airborne to laboratory and industrial use of imaging spectroscopy.

Some of the main features of the HySpex design are:

- Minimization and equalization of point spread function across the FOV and throughout the wavelength range.
- Good matching of point spread function with pixel size.
- Low stray light level.
- Low smile effect and spectral keystone effect.
- Low polarization dependence.
- 2nd order suppression.
- High sensitivity and low noise.
- Automatic shutter
- High acquisition speed and data rates.
- Real time correction of responsivity and dark offset.
- Close-up lenses for operation at short object distances are available.

- Field expanders for doubling the FOV are available.

All HySpex instruments are delivered with:

- A dedicated camera control and data acquisition software package.
- Spectral and radiometric calibration data.
- A detailed test report.
- Users manual and necessary accessories such as cables, power supply and frame grabber.
- Optionally, an API (Application Programming Interface) in Visual C++ can be supplied for application specific software development.
- Exact synchronization with external events (e.g. navigation systems or illumination) is possible through TTL level trigger signals.

In case the HySpex specifications don't meet the requirements of your application, please contact us. NEO designs and delivers customized solutions.

▶ Ageing research has hit bumps in the past decade, as companies marketing drugs touted to prolong life have gone bust (see *Nature* **464,** 480–481; 2010). But organizers of the TAME trial think that the field is now in a better position because animal studies have shown that some drugs and lifestyle practices can extend life by targeting physiological pathways[1].

For instance, the NIA-sponsored Interventions Testing Program, in which investigators at three sites are systematically trialling candidate age-delay treatments, has shown that a handful of interventions convincingly and reproducibly prolong the lives of various strains of mice. Those include cutting down on calorie intake and taking a drug called rapamycin that is used to prevent rejection of transplanted organs.

And researchers from the Novartis Institutes for Biomedical Research in Cambridge, Massachusetts, reported in December that elderly people develop a stronger immune response to an influenza vaccination if they also take a rapamycin-like drug[2]. Rapamycin, which acts on a biological pathway involved in cell growth, is now seen as one of the most promising drugs for delaying ageing, but given over long periods of time it also suppresses the immune system.

SAFETY FIRST

The TAME test is for metformin, which suppresses glucose production by the liver and increases sensitivity to insulin. The drug has been used for more than 60 years and is safe and prolongs healthy life and lifespan in worms[3] and in some mouse strains[1]. Data also suggest that it could delay heart disease, cancer, cognitive decline and death in people with diabetes[4]. Plans call for the trial to enrol 3,000 people aged 70–80 years at roughly 15 centres around the United States. The trial will take 5–7 years and cost US$50 million, Barzilai estimates, although it does not yet have funding.

Matt Kaeberlein at the University of Washington, Seattle, who is running a trial of rapamycin in elderly dogs, says that the concept behind Barzilai's trial is sound. Even though other drugs might be more effective at delaying ageing in animal studies, he says, the many years of experience with metformin in people, combined with data suggesting that it impacts the ageing process in people, make it a good candidate for a first clinical trial in the field.

"It's a smart way to engage the FDA in a discussion about recognizing ageing as an indication that is appropriate for clinical trials," Kaeberlein says. ■

1. Miller, R. A. *et al. J. Gerontol A Biol. Sci. Med. Sci.* **66A,** 191–201 (2010).
2. Mannick, J. B. *et al. Sci. Transl. Med.* **268,** 268ral179 (2014).
3. Onken, B. & Driscoll, M. *PLoS ONE* **5,** e8758 (2010).
4. Bannister, C. A. *et al. Diabetes Obes. Metab.* **16,** 1165–1173 (2014).

Infrared technologies are subject to tight restrictions because of their military applications.

MOISES SAMAN/MAGNUM

TECHNOLOGY

US 'export rules' threaten research

Proposed updates to national-security regulations would restrict collaboration with foreign scientists and industry.

BY ALEXANDRA WITZE

The US government is considering policy changes that could dramatically affect how researchers handle equipment and information that have national-security implications. Among other impacts, scientists would need to reconsider what they can discuss with graduate students from other countries, or when travelling abroad on work trips.

One set of rules would affect technologies such as infrared detectors, which are commonly used for environmental and other types of monitoring but can fall under military restrictions because of their night-vision capabilities. Another set of proposed rules would revise the government definition of "fundamental research" in ways that could affect any scientist who collaborates with industrial partners.

The proposals are part of a long-running effort to overhaul Byzantine regulations that seek to prevent certain information and technologies from reaching countries perceived to be hostile by the United States. These 'export control' rules can create a major — even perilous — headache for US researchers. In 2012, a plasma engineer at the University of Tennessee in Knoxville began serving a four-year jail sentence for violating these rules by working with graduate students from China and Iran while on a US Air Force contract.

Public-comment periods on the proposed rules close on 6 July and 3 August, and science groups are trying to raise awareness of what is at stake. "Once the rules get put in place, it's very hard to dial back if you find them overly aggressive," says Gregory Quarles, a physicist

and board member of the Optical Society, a professional organization in Washington DC that is encouraging its members to study the rules and weigh in with any concerns.

Export control covers both physical equipment that leaves the United States — such as spacecraft components on their way to a launch site, or a laptop computer carrying sensitive information to a conference — and information conveyed to someone from another country. There are two parallel lists that describe which items are controlled, one maintained by the US Department of State and the other by the Department of Commerce. Over the past five years, regulators have been working to relax the system, moving some items from the restrictive state-department list — commonly known as ITAR, for International Traffic in Arms Regulations — to the less tightly controlled commerce-department list. But they have left some of the hardest topics for last.

On 5 May, the departments released the first set of long-awaited proposals for regulating the category that includes sensors and night-vision equipment. Many researchers hoped these would loosen current regulations that they say have impeded research, but that does not seem to be the case. The rules specify performance parameters, such as wavelengths for infrared cameras, that would continue to restrict commercially available sensors that are popular with many researchers for environmental, medical and other applications.

At the University of Rochester in New York, astronomer Judith Pipher develops infrared detectors to observe the cosmos, which are regulated under ITAR because military night-vision goggles also use infrared sensors. Astronomical sensors detect radiation that is one million times less intense than that detected by the military, but neither the current nor the proposed rules take that into account. "I don't think this particular reform is going to get us there," says Pipher, who, before she acquired US citizenship, was once barred from seeing data gathered by infrared instruments that her team was testing.

"We've heard from at least a few institutions that this will totally stifle their ability to work with industry."

The second set of proposed rules could have wider-reaching consequences. It aims to harmonize state and commerce department definitions of terms such as "fundamental research" and "public domain".

In general, the rules state that information developed through fundamental research is considered to be in the public domain and not subject to ITAR controls. But one newly added phrase says that if the research is subject to proprietary review before being published, such as by a company that sponsored the work, then it falls under ITAR.

"We've heard from at least a few institutions that this will totally stifle their ability to work with industry," says Tobin Smith, vice-president for policy at the Association of American Universities in Washington DC.

Any university researcher who has a contract or sponsored research agreement with a company could face a huge load of paperwork. "It will fundamentally change the way we do business," says Elizabeth Peloso, associate vice-president and associate vice-provost for research services at the University of Pennsylvania in Philadelphia.

The new rules would add some needed changes, she adds, such as clarifying that a US researcher can e-mail data to a collaborator elsewhere in the world, as long as those data are encrypted.

After the comment periods close, the state and commerce departments will either issue another round of interim rules for more feedback, or publish whatever final regulations they decide on.

"You asked for reforms, so now you got it," says Kevin Wolf, who oversees the export control reform effort at the commerce department. "If you're an export nerd, now is an exciting time." ■

STANFORD UNIVERSITY

ANN M. ARVIN
VICE PROVOST
DEAN OF RESEARCH

July 2nd, 2015

Directorate of Defense Trade Controls
Office of Defense Trade Controls Policy
Bureau of Political-Military Affairs
U.S. Department of State
2401 E St., N.W.
Washington, D.C. 20522-0112

Re: RIN 1400-AD32

Dear Madam or Sir:

Stanford University appreciates the opportunity to comment on the U.S. Department of State's Proposed Rule (RIN 1400-AD32) regarding the transfer of certain fire control, range finder, and optical and guidance and control equipment from the U.S. Munitions List to the Commerce Control List (CCL). Our institution is grateful for this Administration's effort to advance needed reforms to current export control policies. This letter addresses proposed changes to GPS/GNSS receiving equipment and jamming attenuation systems specifically.

Stanford by express policy engages only in "fundamental research" as defined by U.S. National Security Decision Directive 189 (NSDD 189 - "National Policy on the Transfer of Scientific, Technical and Engineering Information") and implemented by regulation through the Export Administration Regulations (EAR -15 CFR 734.8) and the International Traffic in Arms Regulations (ITAR - 22 CFR 120.11). In pursuing fundamental research, Stanford is committed to the principle of freedom of access by all interested parties to the underlying data, to the processes and to the final results of research. In keeping with this commitment, Stanford does not accept research agreements that limit the publication of results or that limit the participation of researchers in the intellectually significant portions of a project on the basis of citizenship.

Discussion

Stanford University's Department of Aeronautics and Astronautics has been supporting the Federal Aviation Administration (FAA) for over twenty years by conducting FAA-funded fundamental research on GPS technology and its application in civil aircraft. In recent years, the FAA has become understandably concerned about the

Building Ten, Main Quadrangle • Stanford, California 94305-2061
Tel (650) 723-0977 • Fax (650) 725-1653 • aarvin@stanford.edu

effects of GPS/GNSS interference and spoofing and their potential to disrupt civilian aviation. Commercial airborne GNSS receivers encounter a variety of unintentional jammers that could make it difficult to conduct essential operations such as FAA flight inspection, low-altitude operation of rescue helicopters, and airport approach/landing. These jammers can be either personal protection devices (PPDs) or high-power transmitters near airports that are very close to the GNSS L band.

The FAA recognizes that GPS/GNSS antenna techniques, such as adaptive antennas, can significantly mitigate the impact of interference and spoofing on civil aviation. Anti-jamming techniques used in conjunction with commercial airborne GNSS receivers can provide robust civil aviation navigation solutions to enable continued operations and preclude impacts to the national airspace. However, the present restrictions place US universities like Stanford at a disadvantage relative to our European and Chinese counterparts, where robust research is directed at adaptive antennas with multiple elements.

As the use of GNSS anti-jamming technologies in the civil sector continues to increase, it will only become harder to differentiate between their military applications and their bona-fide civil use. Novatel Corporation's GAJT commercial anti-jamming antenna is but just one example. See http://www.novatel.com/solutions/anti-jamming-technology/#products. Anti jamming technology may have been novel and only applicable to military receivers in the past, but in 2015 it is truly applicable to both commercial and military aviation GNSS receivers. The present collaboration between US government agencies regarding oversight of GNSS technology in civil applications is well timed.

Recommendations

Stanford University requests that the Export Control Reform (ECR) Category XII Proposed Rule (RIN 1400-AD32) at paragraph (d) be revised to recognize that jurisdiction for the use of adaptive antenna techniques with associated receiver processing for civilian aviation falls under the Export Administration Regulations (EAR). Stanford further suggests that the use of operational metrics may be more robust than technical measures for revising the rules that surround GNSS antennas. For example, civil aviation should be known to include the operation of rescue helicopters at low altitude, flight inspection, airport approach and airport landing operations. These may be more long lasting than technical constraints based on the number of elements or the achievable null depth.

Two specific recommendations to meet the ECR objective of more precisely defining articles warranting control on the USML follow:

1) Clarify paragraph (d)(6)(iii). As written, this section would appear to inadvertently capture certain GPS receivers specially designed with antennas that are not subject to ITAR under paragraph (d)(7). We recommend that State revise

(d)(6)(iii) to make GPS receiver controls in that paragraph consistent with the antenna controls of (d)(7).

2) Provide **Notes** to paragraphs (d)(6) and (d)(7) that identify control under the EAR when installed on civilian aircraft. We suggest the addition of the following **Notes** to paragraphs (d)(6) and (d)(7):

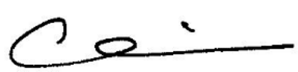
Note to paragraph (d)(6): This paragraph does not control GPS receiving equipment specially designed for civil aviation applications to mitigate interference or spoofing through the use of null steering antennas, or electronically steerable antennas.

Note to paragraph (d)(7): This paragraph does not control GNSS adaptive antenna systems for civil aviation applications.

The Association of University Export Control Officers (AUECO) has submitted detailed comments on the Proposed Rule. In addition to the comments above, we join AUECO in support of their recommendations.

Thank you very much for considering these comments and recommendations. Please do not hesitate to contact me if Stanford can be of help going forward.

Sincerely,



Dr. Ann Arvin
Vice Provost and
Dean of Research

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SUNPOWER

06 July 2015
Ref: TGM-15-007

VIA E-MAIL: DDTCPublicComments@state.gov

Mr. C. Edward Peartree
Director, Office of Defense Trade Controls Policy
U.S. Department of State
PM/DDTC, SA-1, 12th Floor
2401 E Street, NW
Washington, D.C. 20037

Subject: ITAR Amendment—Category XII

Dear Mr. Peartree:

Sunpower® Inc. ("Sunpower"), a subsidiary of AMETEK, Inc., located in Athens, Ohio, submits these comments in response to the U.S. Department of State's proposed changes to Category XII of the U.S. Munitions List published at 80 Fed. Reg. 25821 (May 5, 2015) (RIN 1400-AD32). We are very concerned that the proposed changes would have the anomalous effect of making our current dual-use cryocooler products subject to the International Traffic in Arms Regulations ("ITAR") and thus threaten the viability of our business and eliminate the U.S. commercial cryocooler industrial base.

About Sunpower:

Sunpower was incorporated in 1974 and is based in Athens, Ohio. Sunpower operations are housed in a modern 40,000 square foot facility and employs 78 people. Sunpower currently has annual sales of approximately $12.5M.

Since the invention of the "free-piston" Stirling engine ("FPSE") in the early 1960's by our founder, William Beale, Sunpower's research and development has been applied to the following Sunpower core technologies:

- Stirling engines that produce power from any heat source
- Stirling cryocoolers that use power to move heat

CryoTel® cryocoolers, Sunpower's Stirling cryocoolers, are the result of over thirty years of technical leadership, innovation and evolution in free-piston Stirling technology. The CryoTel® family of cryocoolers is increasingly used in the medical, instrumentation, security, astronomy, telecommunications, and pharmaceuticals markets.

Sunpower's cryocoolers integrate with and support technologies such as high temperature superconductivity, radiation detection, optics, CCD, LNA, gas liquefaction.

As we discuss in more detail below, our main competitors are located in Germany, China, the Netherlands, Israel and Japan.

Proposed Revisions to USML Category XII Affecting Cryocoolers:

Proposed subparagraph (c)(9) of USML Category XII would capture the following:

(9) Integrated infrared focal plane arrays ("IRFPA") dewar cooler assemblies (IDCAs), with or without an IRFPA, having any of the following:

(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

(ii) Active cold fingers;

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category.

Furthermore, proposed subparagraph (e)(7) of USML Category XII would capture the following parts and components:

(7) Integrated IRFPA dewar cooler assembly (IDCA) parts and components, as follows:

(i) Cryocoolers having a cooling source temperature below 218 K and a mean-time-to-failure (MTTF) in excess of 3000 hours;

(ii) Active cold fingers;

(iii) Variable or dual aperture mechanisms; or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b) or (c) of this category.

Why the Proposed Revisions Would Make Sunpower's Dual-Use Cryocooler Products Subject to the ITAR:

In the table below Sunpower has identified the MTTF and lowest temperature of its commercial CryoTel ® cryocoolers. Note that all of these cryocoolers meet the restrictive requirements of the proposed revisions to the USML Cat XII language and that none of these cryocoolers were developed for military or defense purposes.

Sunpower Commercial CryoTel ® Cryocoolers					
	DS 1.5	**DS 2.4**	**MT**	**CT**	**GT**
MTTF	120,000 hrs goal	120,000 hr goal	200,000 hrs	200,000 hrs	200,000 hrs
Minimum Cooling Temperature	40 K	40 K	40 K	40 K	40 K

The proposed USML Cat XII language is overly broad, does not establish a "bright line" between military and non-military cryocooler applications and fails to capture the specific characteristics of military cryocoolers, such as size, weight, or a heat load lift.

The industry accepted definition of cryogenics temperatures is less than 120 K. Paragraphs (c)(9)(i) and (e)(7)(i) identify 218 K as the defining temperature, which by the National Institute of Standards and Technology definition[1] would not be a *cryo*cooler, it would be a cooler. A MTTF of over 3000 hours includes virtually all cryocoolers except specialized Joule-Thompson cryocoolers which have a very short lifetime. ***Joule-Thompson cryocoolers are used in heat seeking missiles to provide cooling to the IRFPA and do not require an extended MTTF. The proposed language does not capture this particular military application but does however capture the majority of the commercial cryocooler applications.***

One of the most commercially successful applications using cryocoolers is in MRI machines found in most all hospitals in the country. These machines use a cryocooler with a Dewar, which reach temperatures below 218 K and have a lifetime of over 3000 hours. The cryocooler mass is in excess of 100 pounds including the compressor, and there is no known military application for these types of cryocoolers. See http://www.shicryogenics.com/products/10k-cryocoolers/ch-202-10k-cryocooler-series/ for a description of this cryocooler. The proposed language will capture cryocoolers used in MRI machines, other medical instrumentation, germanium detectors, pharmaceutical mixers, telecommunications non-military related research, astronomy telescopes, industrial equipment, scientific instruments, and commercial products such as commercial security cameras and thermal imagers. See http://www.xenics.com/en/xco-640 for an example of a commercial camera which uses the Ricor K508 cryocooler. See http://www.sofradir ec.com/products-cooled and http://www.drsinfrared.com/Products/Zafiro640Micro.aspx for examples of thermal imagers that incorporate foreign available DRS and Thales cryocoolers respectively.

A chart of foreign available cryocoolers is shown in Appendix A. All of these cryocoolers meet the cooling and MTTF requirements of the proposed Category XII language. Data sheets for these cryocoolers are publically available. The overwhelming availability of cryocoolers from non-ITAR controlled sources will place constraints on US manufactured cryocoolers which will favor foreign manufactured products. A common question asked by our customers, both foreign and domestic, is "is this cryocooler ITAR controlled?" A customer will pay more and will tolerate less performance and reliability for cryocoolers not subject to ITAR restrictions.

[1] NIST Foundations of Cryocooler short course, given by Ray Radebaugh, Cryogenic Technologies Group, NIST, Boulder, CO. Given July 9th, 2012 at the 17th International Cryocooler conference.

The proposed revisions to the USML Category XII places Sunpower in a precarious position of losing our cryocooler manufacturing capability.

With regard to paragraph (c)(9)(ii) and (e)(7)(ii), *Active Cold Finger* is not known terminology and Sunpower recommends this term be adequately defined before an assessment can be made.

Proposed Alternative Language:

Sunpower is aware of the following military applications for cryocoolers:

- Soldier carry IR
- Vehicle mounted IR
- Aircraft mounted IR
- Missile mounted IR
- Superconducting RF filter
- Superconducting quantum flux sensors for electromagnetic sensing

Cryocoolers in the first four applications are typically used in airborne, soldier, or vehicle-mounted surveillance systems, where size, weight, and performance for a particular cryocooler heat lift is the highest priority. Using such criteria to distinguish cryocooler devices used predominately in such defense applications would capture too much, if not now then in future years. The latest IR detector technology is moving to 120K operating temperatures, up from 77K. The result is considerably smaller and lighter cryocoolers due to reduced heat lift requirements for *both* defense and dual-use applications. In terms of performance, cryocoolers in the 1/2W- 1 W @ 77 K range were once reserved for defense articles, but are now commonly used in non-military applications such as commercial security cameras and commercial thermal imagers. The next generation of cryocoolers for defense applications will be less than 1/3W in the smallest form factor, but cryocooler technology meeting these performance parameters are likely to spread quickly to the dual-use market in applications such as commercial surveillance, agricultural surveying, and scientific research.

For the applications of superconducting RF filters and superconducting quantum flux sensors for electromagnetic sensing, the primary technical requirement is to get the superconducting filter at or around 77K. There is not any other driving specification, and thus it would be very difficult to separate unique defense uses from broader commercial uses based on this criterion.

Thus, Sunpower proposes the following USML Category XII language:

Paragraph (c)(9) - Integrated infrared focal plane arrays ("IRFPA") dewar cooler assemblies (IDCAs), with or without an IRFPA, specially designed for articles controlled in paragraphs (a), (b), or (c) of this category having any of the following:

(i) Cryocoolers specially designed for articles controlled in paragraphs (a), (b), or (c) of this category.

(ii) Active cold fingers specially designed for articles controlled in paragraphs (a), (b), or (c) of this category.

(iii) Variable or dual aperture mechanisms specially designed for articles controlled in paragraphs (a), (b), or (c) of this category or

(iv) Dewars specially designed for articles controlled in paragraphs (a), (b), or (c) of this category.

(v) *Joule-Thomson (JT) self-regulating cryostats "specially designed"* for articles controlled in paragraphs (a), (b), or (c) of this category.

Paragraph (e)(7) – Delete the proposed paragraph since parts and components are addressed in Sunpower's recommended (c)(9) language above.

We believe Sunpower's proposed language will capture cryocoolers used for military purposes while releasing non-military use cryocoolers, enabling the U.S. cryocooler industry to compete globally over the long-term. In particular, it supports an *innovative* U.S. cryocooler industrial base of secure and reliable suppliers, now and in the future, to meet the needs of U.S. armed services.

If you wish to discuss Sunpower's comments, please do not hesitate to contact me via telephone at (740) 566-1085 or via e-mail at tom.matros@ametek.com. Sunpower also authorizes Mr. Gary Stanley of Global Legal Services, P.C., in Washington, DC, to discuss our comments with relevant U.S. Government officials. You can reach Mr. Stanley by telephone at (202) 352-3059 and by e-mail at gstanley@glstrade.com.

Thank you very much for your consideration of our input on this very important matter to our company.

Respectfully Submitted,

Tom Matros

Tom Matros
Contracts and Export Compliance

APPENDIX A

FOREIGN AVAILABILITY

Manufacturer	Country of Origin	Cooler	MTTF	Temperature	Weight	cooling power @77K
AIM	Germany	SF070	> 25,000 hr	60 K	850gr	500mW
AIM	Germany	SX095	>15,000 hr	60 K	760gr	600mW
AIM	Germany	7062	> 4,000 hr	59 K	450 gr	500mW
AIM	Germany	SF100A	> 25,000 hr	60 K	1.8kg	1800mW
AIM	Germany	SL150B	>8000 hr	28 K	2.3kg	1000mW
AIM	Germany	SL400A	>8000 hr	28 K	3.1kg	3700mW
AISIN SEIKI	Japan	SPR-05	>3000 hr	< 218 K	18kg	8000mW
Hymatic	United Kingdom	SAX101	> 45,000	<70 K	3kg	2700mW
Le Tehnika	Slovenia	SRI401	> 10,000 hr	< 70 K	470 gr	230mW
Le Tehnika	Slovenia	SRL301	> 5000 hr	< 70 K	650gr	400mW
Lihan	China	TC4148	> 50,000	< 40 K	4.3kg	9500mW
Lihan	China	TC4177	> 50,001	< 40 K	4.3kg	9500mW
Ricor	Israel	K562S	> 10,000 hr	< 95 K	185 gr	300mW
Ricor	Israel	K570	> 30,000 hr	< 70 K	930gr	1000mW
Ricor	Israel	K543	> 15,000 hr	< 70 K	470gr	1000mW
Ricor	Israel	K527	> 30,000 hr	< 95 K	345 gr	500mW
Ricor	Israel	K563	> 8,000 hr	< 70 K	290 gr	280mW
Ricor	Israel	K529N	> 25,000 hr	< 70 K	290 gr	250mW
Ricor	Israel	K535	> 30,000	< 70 K	9.5kg	7000mW
Thales	Netherlands	RM1	> 5000 hr	<110 K	250 gr	400m W @110K
Thales	Netherlands	RM2	> 10,000 hr	<77 K	275 gr	400m W
Thales	Netherlands	RM3	no data	no data	450 gr	550m W
Thales	Netherlands	UP8497	> 30,000	< 70 K	650 gr	650 mW
Thales	Netherlands	UP 7086	> 30,000	< 70 K	1300gr	600 mW
Thales	Netherlands	UP 7088	> 30,000	< 70 K	1.9 kg	1900mW
Thales	Netherlands	UP 7098	> 30,000	< 70 K	1.7 kg	2000mW
Thales	Netherlands	LSF 9508	> 45,000	< 70 K	1.7 kg	1050mW
Thales	Netherlands	LSF 9599	> 45,000	< 70 K	1.7 kg	2300mW
Thales	Netherlands	LPT9310	> 90,000	< 70 K	7kg	5100mW
Thales	Netherlands	LSF9510	> 90,000	< 70 K	2.1 kg	9000mW
Thales	Netherlands	LPT9710	> 90,000	< 70 K	16kg	1500mw
Twinbird	Japan	SC-UF01	> 40,000	< 70 K	9.9kg	8000mW

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June 29, 2015

United States Department of State

Directorate of Defense Trade Controls

Dear Sir/Madam:

RESPONSE TO REQUEST FOR COMMENTS RE: USML CATEGORY XII

On May 5, 2015, the Department of State, Directorate of Defense Controls (DDTC) issued a Federal Register Notice soliciting comments from industry on the implementation of Export Control Reform (ECR) with respect to fire control, range finder, optical and guidance and control equipment and setting the deadline for such comments as July 6, 2015. Teledyne Optech ("Optech") respectfully submits the following comments. Thank you for your consideration.

EXECUTIVE SUMMARY

We appreciate the USG's efforts to more accurately describe the articles in this category in order to establish a "bright line" between the USML and the CCL for the control of these articles. However, the proposed rules place new controls on certain existing Optech commercial products that will negate many of the intended benefits of ECR with respect to the items in this category, including laser rangefinders and light detection and ranging ("lidar") systems.

Although Optech is based in Canada and many of our laser rangefinders and lidar systems are manufactured in Ontario, we also manufacture bathymetric survey lidar systems in Mississippi.

Because we are one of the only lidar manufacturers in the world that manufactures commercial lidars in the United States, we are concerned that the proposed changes to USML Category XII could uniquely disadvantage our U.S. operations when competing for commercial applications against European and Asian competitors.

Such proposed revisions to Category XII(b) would result in the transfer of many commercial products to the USML that were previously not USML controlled. These products were designed, and are predominately used, for commercial applications. They were not designed for military use.

The fact that existing commercial laser rangefinders and lidar products may possess parameters or characteristics that provide a critical military advantage means that the proposed control of these

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commercial products would cross the "bright line" from the CCL to the USML. As such, we believe that it would be in the best interest of the Government and industry to clearly specify that such items are controlled in the USML only if they are specially designed for military use.

Optech develops and manufactures commercial lidar and camera survey instruments for airborne, mobile and terrestrial mapping applications, as do many other companies.

Detailed comments are provided below. The specific categories for which we are providing comments are:

Paragraphs (b)(3), (b)(4), (b)(6) and (b)(8)(ii,v,vi)

Comments to Category (b) – Lasers, and laser systems and equipment

1. ***(3) Laser rangefinders having any of the following:***
(i) Q-switched laser pulse; or
(ii) Laser output wavelength exceeding 1,000 nm;

Comment: We are concerned that this wording, as proposed, would capture many laser rangefinders that were developed, and are currently used, for commercial applications. These products, which were not specially designed for military applications, or to military specifications, may employ a Q-switched laser pulse and operate at a laser output wavelength exceeding 1,000 nm.

We understand that the particular laser rangefinders that are of interest to the government would be used primarily for locating military targets. These military rangefinders are typically designed for long range (several kilometers), with an accuracy between one and five meters. Commercial rangefinders, on the other hand, are required to have much better accuracy (e.g. 5 cm) and lower range capability (normally less than one kilometer).

To prevent the inadvertent control of laser rangefinders on the ITAR that are in normal commercial use, we suggest the following wording for paragraph (b)(3):

"(3) Laser rangefinders specifically designed for military use, and having any of the following:
(i) Q-switched laser pulse; or
(ii) Laser output wavelength exceeding 1,000 nm;"

2. ***(4) Targeting or target location systems or equipment incorporating or specially designed to incorporate a laser rangefinder controlled in paragraph (b)(3) of this category, and incorporating or specially designed to incorporate a Global Navigation Satellite System***

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(GNSS), guidance or navigation article controlled in paragraph (d) of this category (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km range);

Comment: If the suggested changes are made to paragraph (b)(3), then we suggest no changes to this language.

3. ***(6) Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km);***

Comment: Commercial products, in some cases, incorporate an ITAR-controlled IMU (an article controlled in this subchapter), which is required for accurate topographic mapping. In other cases, a non ITAR-controlled IMU is incorporated into the same product. We suggest removing the wording "*or specially designed to incorporate*", so that the product is controlled only if it physically incorporates an article controlled in this subchapter.

Such commercial products were not designed for military use, so it would seem unwise to have such items ITAR controlled if they do not incorporate an ITAR item. Several Optech products fall into this category. We are concerned that having these commercial products become subject to the USML would severely limit sales potential and control products that have been sold commercially without a BIS license for many years.

4. ***(8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):***

(ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);

Comment: Many commercial lidar systems, operating at wavelengths exceeding 1,000 nm, currently have the capability to detect power lines having a diameter of 10 mm, from a distance of 500 m. Such products were designed for commercial topographic mapping and not specially designed for military use. Due to their inherent design, these systems are capable of carrying out power line mapping for commercial applications, and have been doing so for over 15 years. For example, Optech's commercial

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Orion C200 airborne laser terrain mapper is able to detect a fishing line (< 1 mm diameter) from an altitude of 200 m. In this case, our commercial systems have already demonstrated a capability that exceeds the proposed ITAR limits.

To avoid controlling such items on the ITAR, that are in normal commercial use, we suggest the following wording to paragraph (b)(8)(ii):

> ***"(ii) Aircraft systems or equipment specially designed for military use and having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);"***

5. ***(8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):***

> ***(v) Systems or equipment that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs);***

Comment: Some commercial airborne lidar bathymetric systems, designed for measuring water depth and mapping water-bottom topography, could be used for automatic identification of submersibles, due to their inherent design. Optech has several products in this category, including our Aquarius and Titan systems. These products were not designed for military applications. As with the previous comments, to avoid inadvertent control of such items on the ITAR, we recommend the following wording for paragraph (b)(8)(v):

> ***"(v) Systems or equipment specially designed for military use and that automatically classify or identify submersibles, mines, unexploded ordnance or improvised explosive devices (IEDs);"***

6. ***(8) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (MT if designed or modified for rockets, missiles, SLVs, drones, or unmanned aerial vehicle systems capable of delivering at least a 500 kg payload to a range of at least 300 km):***

> ***(vi) Systems or equipment specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;***

Comment: Similar to category *(8)(v)*, some commercial ground-based laser imaging and mobile mapping products, not specially designed for military use (e.g. for obstacle avoidance), can be useful for obstacle avoidance applications, due to their inherent design, either as is, or with minor modifications. Optech has already demonstrated how some of the commercial products – ILRIS and Lynx – could be used for obstacle avoidance applications.

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As with the previous comments, we suggest the following wording for paragraph (b)(8)(vi):
" ***(vi) Systems or equipment specially designed for military use and specially designed for obstacle avoidance or autonomous navigation in ground vehicles controlled in Category VII;"***

Inputs on Requested Items

1. ***Items proposed for control on the USML or the CCL that are not controlled on the Wassenaar Arrangement's Munitions List or Dual Use List.***

Comment: Lidar systems are presently not controlled on the Wassenaar Arrangement's Munitions or Dual Use List, whereas lidar systems are proposed for control in USML Category XII(b) (6),(7) and (8).

Lidar systems were previously not controlled on the USML, unless they specifically incorporated an ITAR-controlled item. Lidar systems are not controlled on the CCL, except for ECCN 6A008.j, which was introduced a few years ago:

j. Being "laser" radar or Light Detection and Ranging (LIDAR) equipment and having any of the following:
j.1. "Space-qualified";
j.2. Employing coherent heterodyne or homodyne detection techniques and having an angular resolution of less (better) than 20 µrad (microradians); *or*
j.3. Designed for carrying out airborne bathymetric littoral surveys to International Hydrographic Organization (IHO) Order 1a Standard (5th Edition February 2008) for Hydrographic Surveys or better, and using one or more lasers with a wavelength exceeding 400 nm but not exceeding 600 nm;
Note 1: *LIDAR equipment specially designed for surveying is only specified by 6A008.j.3.*

As indicated in the note to 6A008.j, lidar equipment specially designed for surveying is only specified by 6A008.j.3.

2. ***Although the proposed revisions to the USML do not preclude the possibility that items in normal commercial use would or should be ITAR-controlled because, e.g., they provide the United States with a critical military or intelligence advantage, the U.S. government does not want to inadvertently control items on the ITAR that are in normal commercial use. Items that would be controlled on the USML in this proposed rule have been identified as possessing parameters or characteristics that provide a critical military or intelligence advantage. The public is thus asked to provide specific examples of items, if any, that would be controlled by the revised USML Category XII that are now in normal commercial use. The examples should***

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demonstrate actual commercial use, not just potential or theoretical use, with supporting documents, as well as foreign availability of such items.

Comment: As mentioned previously, Optech develops and manufactures lidar and camera survey instruments for airborne, mobile and terrestrial mapping applications, including the following products:

- Orion – airborne lidar system for terrain mapping
- Galaxy - airborne lidar system for terrain mapping
- Pegasus - airborne lidar system for terrain mapping
- Titan – airborne lidar system for terrain mapping
- Aquarius – airborne lidar system for bathymetric mapping
- CZMIL - airborne lidar system for bathymetric mapping
- ILRIS – ground-based laser imaging system
- Lynx – lidar mobile mapping system

The Orion, Galaxy, Pegasus, Titan, Aquarius and CZMIL are all airborne laser terrain mapping systems. The Orion, Galaxy and Pegasus are used strictly for topographic mapping. The CZMIL and Aquarius are designed primarily for mapping underwater terrain, but can be used for topographic mapping . The Titan is designed for both topographic and bathymetric mapping.

The ILRIS is a ground-based tripod-mounted laser scanning and imaging system, used to produce 3-D imagery of scanned scenes. The Lynx is a ground-based mobile mapping lidar system used to scan outdoor imagery of buildings, etc. from a moving platform.

These products were developed for, and are presently in, normal commercial use. Currently, they are not controlled by the USML and do not require a Commerce Department license to be exported as CCL items. However, under the new proposed rules, they would be subject to ITAR Controls.

All of the above products were originally designed to incorporate an ITAR-controlled IMU, due to its small size and high accuracy – performance characteristics necessary for commercial surveying and mapping applications. Recently, however, the design of these products has been modified to accept IMUs that are not ITAR controlled, for those applications where size and/or accuracy is not as critical. With the current proposed rules, these products may be caught by paragraph (b)(6).

Orion, Galaxy, Pegasus and Titan are airborne lidar survey instruments that operate at wavelengths of 1064 nm and/or 1540 nm and incorporate lasers with high pulse-repetition-rate lasers (up to 500 kHz) and pulse energies up to 50 microJoules. These specifications, which are critical for commercial surveying and mapping applications, are also sufficient for detecting power lines. In fact, some of our products have been used for mapping power lines as long as 15 years ago. With the current proposed rules, these products would now be caught by paragraph (b)(8)(ii).

Aquarius, Titan and CZMIL are airborne lidar survey instruments that were developed for commercial survey applications, including water depth measurement, mapping water-bottom topography, and water-

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column measurements. Due to their inherent design – incorporating high pulse rate visible lasers (532 nm) with sufficient pulse energy – they are able to detect submersibles in the water column. With the current proposed rules, these products would now be caught by paragraph (b)(8)(v).

ILRIS and Lynx are commercial ground-based lidar systems that were designed for 3-D imaging and mobile mapping. Due to their inherent design – incorporating high pulse-rate lasers with small beam divergence – they could be used for obstacle avoidance applications; e.g. detecting ground vehicles. With the current proposed rules, these products would now be caught by paragraph (b)(8)(vi).

Brochures for the above products are attached to this document.

Also, listed below are the websites of some of our European and Asian competitors that develop laser rangefinders and lidar systems in normal commercial use that are similar to Optech's products:

- Leica Geosystems – http://www.leica-geosystems.com/en/index.htm
- Riegl – http://www.riegl.com/
- Measurement Devices Limited (MDL) – http://www.renishaw.com/en/spatial-laser-measurement--25585
- IGI – http://www.igi.eu/news.html
- Airborne Hydrography AB – http://www.airbornehydro.com/

CONCLUSIONS

1. It is our understanding that the intent of U.S. ECR is that items that are in normal commercial use and not specially designed for military use would not become subject to the USML. At the same time, we recognize that such items may possess parameters, or characteristics, that provide a critical military or intelligence advantage. Doing so crosses the "bright line" between the USML and the CCL. We believe that the USML should not control such items unless they have been specially designed for military use. As such, we recommend additional wording that would only capture items that are specifically designed for military use.

2. The existing USML Category XII(b) only refers to "lasers specifically designed, modified or configured for military application…". This clearly excludes Lidar systems that were designed, and are currently used, for commercial applications. The proposed revisions would have a negative impact on industry and the future exports of these products. International business would be negatively affected by having commercial items controlled in the USML, as many companies and agencies are reluctant to procure

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items that are ITAR controlled. Teledyne Optech has had such responses from potential customers.

We appreciate DDTC's consideration of these issues.

Yours sincerely,

Glenn Farrington
Executive Vice President, Operations

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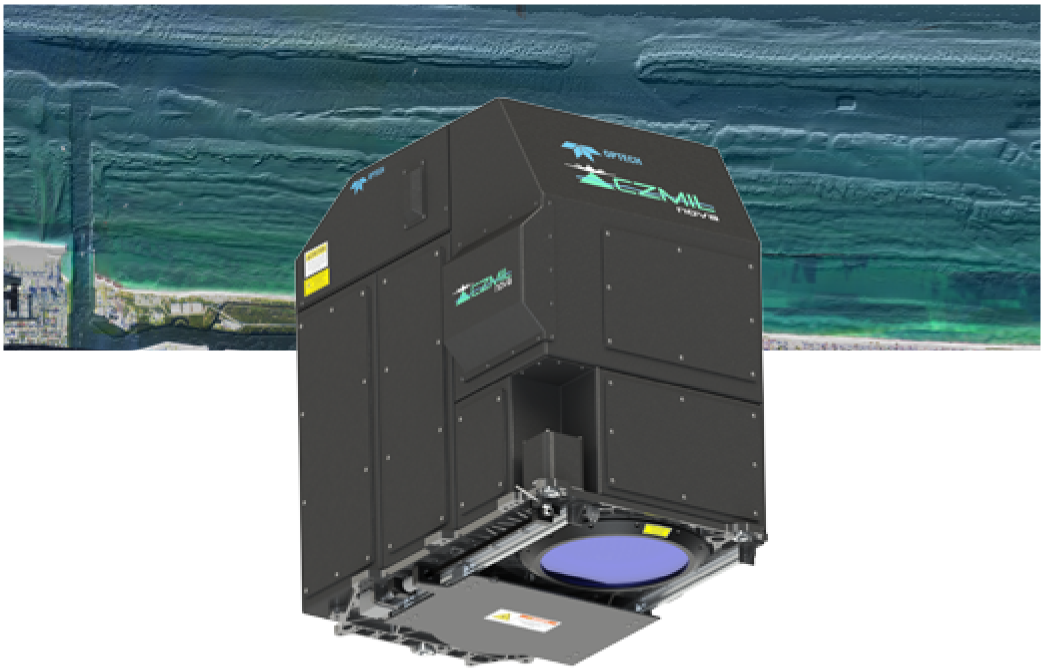
Optech CZMIL Nova

Airborne Bathymetric Lidar Summary Specification Sheet

Applications

- Coastal management
- Harbor and navigation channel inspection
- Beach/coastal erosion monitoring
- Nautical charting
- Aquatic ecosystems management
- Rapid environmental assessment
- Underwater object detection

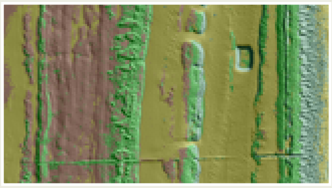


The most productive airborne system for seamless topography and bathymetry in real-world water quality conditions

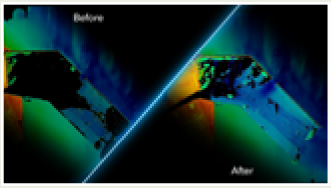
Optech CZMIL Nova is an innovative airborne coastal zone mapping system that produces simultaneous high-resolution 3D data and imagery of the beach and shallow water seafloor, including coastal topography, benthic classification and water column characterization. CZMIL Nova performs particularly well in shallow, turbid waters. Its bathymetric lidar is integrated with a hyperspectral imaging system and digital metric camera. Optech HydroFusion, a powerful end-to-end software suite, handles all three sensors—from mission planning through to fused lidar and imagery data sets.

- Only system tested against military specs such as shock & vibration and validated by US and foreign government agencies
- Best seamless topo/bathy capability in clear waters up to 80 m and unmatched results in turbid waters
- The CZMIL Nova is optimized for weight and size, and can be mounted in aircraft as small as a Piper Navajo
- Best operational productivity with all in one HydroFusion workflow and data fusion software

Optech CZMIL Nova was designed by Teledyne Optech for the U.S. Government under the auspices of the U.S. Army Corps of Engineers (USACE) and the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). It was built and tested by Optech with the assistance of the University of Southern Mississippi (USM).



Bottom Classification



Turbid Water Performance

Seamless Topo/Bathy

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Optech CZMIL Nova

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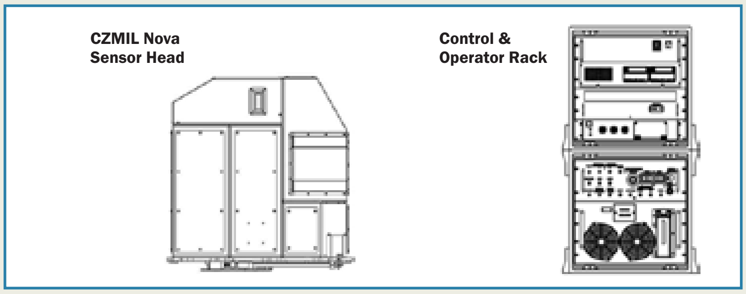
Advantages

- Accurate and seamless topography and water-depth measurements
- Short laser pulse widths enable true shallow-water bathymetry
- Circular scan pattern provides two 'looks' per target, for optimal object detection
- Web-based interface for real-time in-field remote diagnostics
- Simultaneous high-density topo/bathy data from a single laser
- Segmented detector capable of up to 70,000 measurements/second
- Lidar, hyperspectral, and RGB camera integrated on-board
- Weight and design optimized for airworthiness and military standards

	Parameters	Specifications
General Specifications	Operating altitude	400 m (nominal), up to 1,000 m
	Aircraft speed	140 kts (nominal)
	Hyperspectral sensor	CASI-1500H
	Digital cameras	T4800i
	Positioning & GPS/GNSS	Applanix POS AV™
	Positioning system	OmniSTAR capable (subscription required)
Lidar Hydrographic Mode	Shallow channels measurement rate	70 kHz
	Shallow channels maximum depth	$2/K_d$ (bottom reflectivity > 15%)
	Deep channel measurement rate	10 kHz
	Deep channel maximum depth	$4.2/K_d$ (bottom reflectivity > 15%)
	Depth measurement accuracy	$\sqrt{(0.3^2+(0.013d)^2)}$ m, 2σ, 0 – 30 m
	Horizontal accuracy	(3.5 + 0.05d) m, 2σ
	Scan angle	20° circular
	Swath width	70% of operating altitude
	Laser classification	Class 4 laser product: IEC 60825-1 Ed. 3.0 2014
Lidar Topographic Mode	Measurement rate	80 kHz
	Horizontal accuracy	±1 m, 2σ
	Vertical accuracy	±15 cm, 2σ
Physical	Power requirements	85 A for Lidar/camera @ 28 VDC and 95A @28VDC with CASI
	Operating temperature	0°C to 40°C
	Storage temperature	-10°C to +60°C
	Humidity	0-95% non-condensing
	Sensor head	89 W x 60 D x 90 H cm; 175 kg
	Control & operations rack	59 W x 56.5 D x 106 H cm; 112 kg
	Data processing software	CZMIL HydroFusion (Windows-based)



Optech

Applications

- Wide-area mapping
- Urban mapping
- Natural resource management
- Engineering & infrastructure modeling
- Powerline & transportation corridor

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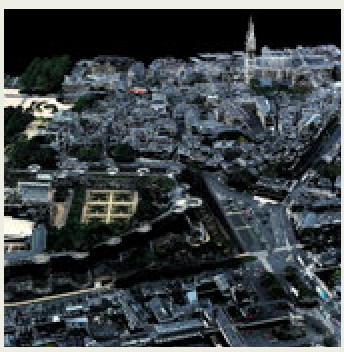
Optech Galaxy

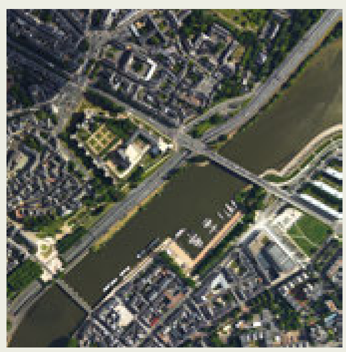
Airborne Lidar System

High-performance, ultra-compact, airborne lidar sensor for high-altitude, wide-area survey applications

The new Optech Galaxy is the epitome of single-beam sensor design, rivaling much larger dual-beam sensors with its high point density and collection efficiency. A descendant of the popular Orion platform, Galaxy is quite simply the smallest sensor on the market with the greatest capability, representing a leap ahead of its competitors in every way. Whether gyro-stabilized or fixed-mounted, high-altitude or low, one camera or six, Galaxy offers incredible collection efficiency and configuration flexibility with the highest data precision and accuracy possible.


Continuous Operating Envelope

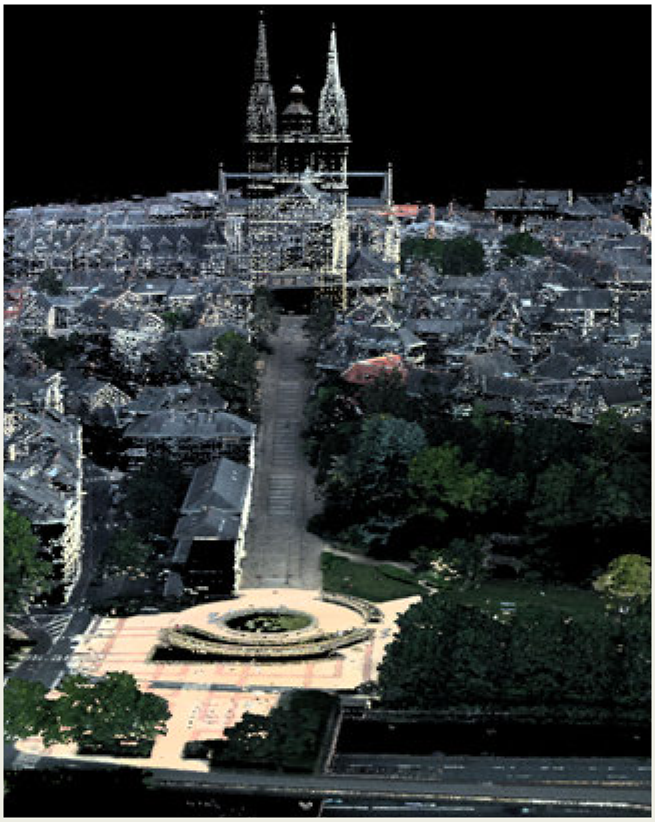

Increased Vertical Density

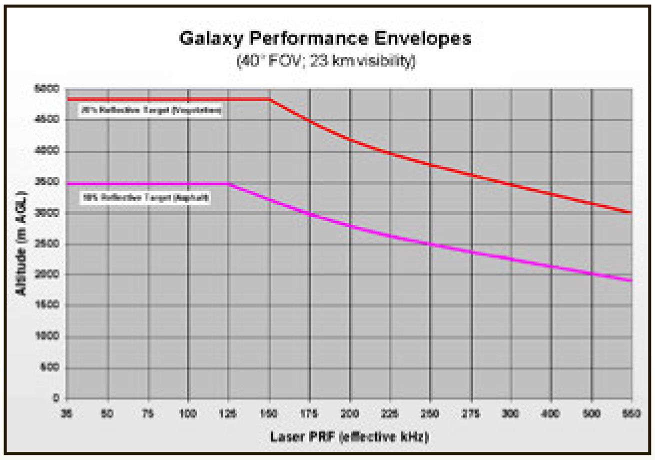

Seamlessly Integrated Cameras

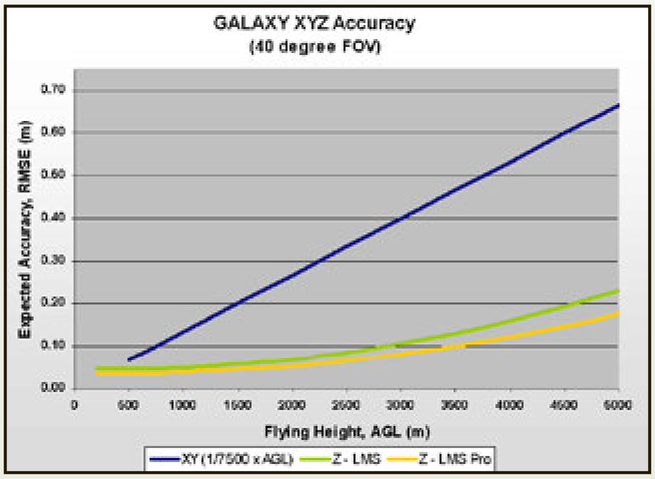
Optech

The Optech Galaxy Advantage

- High-performance laser and scanner provide exceptional performance for maximum application flexibility.
- Continuous operating envelope accommodates high-relief terrain with no data gaps or loss of density across multipulse transition zones.
- Capable of up to 8 returns per emitted pulse, Galaxy guarantees the highest vertical density possible without the processing and storage burden of voluminous waveform capture.
- Unique Swath Tracking mode maintains constant-width flightlines for consistent data density in variable terrain.
- Unique real-time sensor protocol enables in-air point cloud display for true-coverage verification and immediate rapid-response deliverables in LAS format.
- Optech FMS Flight Management Suite provides integrated planning with simultaneous control and monitoring capability for up to 8 sensors.
- Industry-leading data precision and accuracy enables survey-grade raw data for the highest quality map products possible.
- Gyro-stabilized and multi-sensor mounts maximize collection efficiency and enable custom sensor suites tailored to your application requirements.
- Powerful Optech LMS Lidar Mapping Suite automates sensor calibration, maximizes laser point accuracies and quantifies project accuracy deliverables.







What is the secret to Galaxy's *performance advantage?*

POWERED BY PulseTRAK™

PulseTRAK™ is an innovative set of lidar technology enhancements that significantly increases sensor reliability and collection efficiency, improves data quality, and greatly simplifies the collection process.

These new enhancements include:

1. High-Performance Scanner

A new, high-performance galvometric scanner forms the foundation of Galaxy's exceptional performance capability. Featuring extremely high torque and minimal electrical inductance, the new scanner provides superior scan speeds at reduced voltages for a significant boost in performance, reliability, and scan linearity, enhancing data quality and point distribution. Coupled with an innovative atmospheric point inhibitor, Galaxy provides the highest quality data possible right out of the box.

- Higher scan velocity and scan product for efficient point distribution at faster laser sampling rates.
- Improved scanner stability produces maximum calibration consistency.
- Innovative atmospheric point inhibitor enables "cleaner" raw data and reduces post-processing filtering.

2. Continuous Operating Envelope

PulseTRAK™ technology enables a truly continuous operating envelope by eliminating the data coverage gaps and irregular point density commonly found with other multipulse-equipped sensors. This feature greatly simplifies mission planning and produces consistent data distribution throughout the entire data set, even across receiver "blind" zones.

- Enables consistent point density with no more receiver "blind" zones.
- Complete collection freedom irrespective of terrain variability significantly enhances efficiency.
- Greatly simplifies mission planning.

3. Swath Tracker

PulseTRAK™ technology enables Swath Tracking mode by using the programmable galvometric scanner to create a real-time dynamic FOV that maintains constant swath width and point distribution in varying terrain heights.

- Maintains regular point distribution and constant-width flightlines despite changes in terrain height.

4. Real-time Sensor Protocol

PulseTRAK™ technology now incorporates Optech's real-time sensor protocols to enable in-air target observation and collection monitoring, significantly increasing collection confidence.

- Real-time XYZi point display enables true-coverage verification over the entire operating envelope, even across multi-pulse transition zones.
- In-air target detection and monitoring confirms detection of small targets such as powerlines in real-time.
- Real-time LAS file generation produces immediate data deliverables.

Optech

Optech Galaxy Specifications

Parameter	Specification
Laser Configuration	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Beam divergence	0.25 mrad (1/e)
Operating altitudes (1,2,3,4)	150-4700 m AGL, nominal
Effective pulse repetition frequency	Programmable, 35-550 kHz
Laser range precision (5)	< 0.008 m, 1 σ
Scan angle (FOV)	Programmable, 0-60°
Swath width	Programmable, 0-115% of AGL
Scan frequency	Programmable, 0-100 Hz advertised (0-200 scan lines/sec)
Sensor scan product	1400 maximum
Absolute horizontal accuracy (2,3)	1/ 7,500 × altitude; 1 σ
Absolute elevation accuracy (2,3)	< 0.03-0.20 m RMSE from 150-5000 m AGL
Sensor Configuration	
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy IMU (IMU-8)
Flight management system	Optech FMS
PulseTRAK™	Continuous operating envelope; Swath Tracker mode; real-time XYZi
Range capture	Up to 8 range measurements, including last
Intensity capture	Up to 8 intensity returns for each pulse, including last (12-bit)
Roll compensation	Programmable; ±5° at 50° FOV; increasing as FOV is reduced from 50°
Minimum target separation distance	< 0.7 m (discrete)
Data storage	Internal solid state drive SSD (SATA II)
Power requirements	28 V; 300 W; 12 A
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg — PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C
Optional Peripherals	
ITAR-free IMU	FMU-301 (IMU-46)
External data storage	Ruggedized, removable 2.5” SSD (SATA II)
Image capture	Compatible with all Optech CS-Series and most 3rd party digital metric cameras
Full waveform capture	12-bit Optech IWR-2 Intelligent Waveform Recorder with removable SSD
Gyro-stabilization	SOMAG GSM 3000/4000 integration kit
Multi-sensor mounts and pods	2 and 4-station machined aluminum sensor mounts (aircraft and/or helicopter) Carbon-fiber heli-pod sensor mount supporting nadir and fore/aft oblique cameras Heli-sensor pod and mount options for Bell 206 (includes STC)

1. Target reflectivity ≥20%.
2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite.
3. Angle of incidence ≤20°
4. Target size ≥ laser footprint
5. Under Optech test conditions, 1 sigma

Optech

ILRIS Terrestrial Laser Scanner

Summary Specification Sheet

Key Features

- 10 kHz repetition rate
- High-precision mode
- Rapid survey method
- Extended-range mode

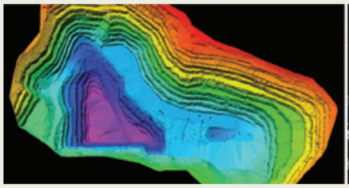
Benefits

- Fast data collection
- Improved accuracy
- Reduced processing time
- Long-range scanning

Providing the Industry with the Leading Terrestrial Laser Scanner (TLS)

The Optech ILRIS Terrestrial Laser Scanner enables surveyors to capture and define the world point by point. From single to multiple scans, you can coordinate and document your subject in 3 dimensions. An ideal complement to a surveyor's tool-kit, the ILRIS brings high-density engineering and survey-grade data to the table—even at extremely long range.

The Optech ILRIS Terrestrial Laser Scanner is a fully portable, laser-based, ranging and imaging system for the commercial survey, engineering, mining and industrial markets. A compact and highly integrated instrument with digital image capture and sophisticated software tools, the ILRIS is an industry-leading solution that addresses the needs of commercial users. The ILRIS is field-ready and requires no specialized training for deployment. Similar in size to a motorized total station, with an on-board high-resolution digital camera and a large-format LCD viewfinder, the ILRIS has a visual interface similar to that of a digital camera.



Mining

Civil Engineering

Geological Survey

ILRIS Terrestrial Laser Scanner

Parameter	ILRIS-HD	ILRIS-HD-ER	ILRIS-LR
Range 80% reflectivity	1250 m (4101 ft)	1800 m (5905 ft)	3000 m (9842 ft)
Range 10% reflectivity	400 m (1312 ft)	650 m (2132 ft)	1330 m (4363 ft)
Minimum range	3 m (9 ft, 10 in)		
Laser repetition rate (peak and effective PRF) [1]	10,000 Hz		
Efficiency (effective PRF/peak PRF)	100%		
Raw range accuracy [2,3]	7 mm @ 100 m		
Raw range accuracy [3,4]	4 mm @ 100 m		
Raw angular accuracy	8 mm @ 100 m (80 µrad)		
Scanner Performance			
Field of view	40° × 40° (-20° through 90°, -90° through 20° with 3_6D option)		
Minimum step size [5]	0.001146° (20 µrad)		
Maximum density (point-to-point spacing)	2 cm @ 1000 m (1 in @ 3280 ft)		
Rotational speed	0.001 to 20°/sec		
Rotational step size (minimum)	0.001146° (20 µrad)		
Beam diameter ($1/e^2$)	19 mm @ 100 m		27 mm @ 100 m
Beam divergence	0.008594° (150 µrad)		0.014324° (250 µrad)
Laser wavelength	1535 nm		1064 nm
Laser class [6,7]	1 or 1M		3
Integrated camera	3.1 MP		
Physical and Environmental			
Size (L × W × H)	320 × 320 × 240 mm (12.6 × 12.6 × 9.5 in)		
Weight	14 kg (31 lbs)		
Operating temperature	-20°C to +40°C (-4°F to +104°F)		
Storage temperature	-20°C to +50°C (-4°F to +122°F)		
Relative humidity	0 – 95% non-condensing		
Power consumption	75 W		
Battery operation (standard battery pack, hot-swappable)	5 hours operation		
Data storage	Removable USB drive		
Optional Configuration			
3_6D	Automated pan/tilt base (7 kg/16 lbs)		
MC	Motion compensation option: Enables GPS timestamping (from INS system)		

Standard Accessories

Scanner control software for Windows-based computers	Data extraction software to generate user-selectable file formats
Automated alignment software	2.0-GB USB memory drive
User manuals	Universal AC voltage power supply
Interconnect power/battery cables	Rugged carrying case

Optional Accessories

Manual pan/tilt base	GPS/external camera mounting kit
PDA, UMPC, Notebook PCs	Batteries and chargers
Backpack	Cold-weather jacket

1 PRF is pulse repetition frequency.
2 All ranges quoted are with ER Mode enabled.
3 All accuracies are 1 sigma, as performed under Optech test conditions. Details available on request.
4 Average of 4 shots minimum.
5 Independent fully-selectable vertical and horizontal step size selection.
6 Laser class in accordance with IEC 60825-1 and US FDA 21 CFR 1040.
7 ILRIS-LR laser Class 3 when viewing between 0-114 m (0-374 ft). Class 1M when viewing at ranges greater than 114 m (374 ft).

Data output to a variety of user-selectable formats and XYZ coordinates, including return intensity and digital photograph.
User interface: PDA, UMPC, tablet or notebook via wired/wireless connection (802.11b/g).
Digital imaging: Internal 3.1-Megapixel camera with calibration file for creating true color RGB point clouds.
Display: On-board 6.5" XVGA color LCD panel for image, system status, and data display.

Optech

ORION H300

Airborne Lidar Summary Specification Sheet

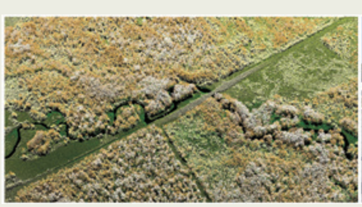
Applications

- Mountain & glacier surveying
- Floodplain mapping
- Forestry management
- Asset management

High Density at 4000 m!

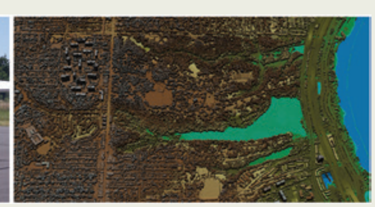
High-performance, ultra-compact, airborne lidar sensor for high-altitude, **wide-area survey** applications

The Orion H300 lidar survey system is the most versatile system on the market today. Whether gyro-stabilized or fixed-mounted, the Orion H300 has an incredibly wide operating envelope ideal for those surveyors that desire a universal sensor with the flexibility to deliver on low-altitude corridors, as well as high-altitude, wide-area collects. Laden with performance features, the H300 offers exceptional collection efficiency and productivity, while also boasting industry-leading measurement precision to provide the highest possible quality data sets. The Orion H300 is the perfect blend of performance and size for those looking for a lidar survey system suitable for all application spaces.



Forestry Management

Wide-Area Surveys



Floodplain Mapping

Optech

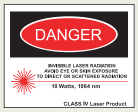
ORION H300

The ALTM Orion Advantage

- High-performance laser provides exceptional range performance for maximum application flexibility
- Industry-leading data precision and accuracy ensures the highest quality map products possible
- Tightly-coupled inertial and Virtual Reference System processing technology enables steep turns and extended baselines for cost effectiveness
- Optech FMS Flight Management Suite provides integrated planning with simultaneous control and monitoring capability for up to 8 sensors
- Gyro-stabilized and multi-sensor mounts maximize collection efficiency and enable custom sensor suites tailored to your application requirements
- Unique real-time LAS file generator for in-air point cloud display enables precise coverage verification and immediate rapid response deliverables
- Ultra-compact, full-system design enables small-footprint installations with limited space
- Powerful Optech LMS lidar processing software automates lidar rectification and is tuned to maximize project-wide accuracies
- Fully compatible with Optech's line of scalable RGB, IR, multispectral and thermal cameras, configurable to your application requirements

Parameter	Specification
Operational envelope (1,2,3,4)	150-4000 m AGL, nominal
Effective laser repetition rate	Programmable, 35-300 kHz
Laser wavelength	1064 nm
Elevation accuracy (2,3)	<3-15 cm; 1 σ
Horizontal accuracy (2,3)	1/7500 x altitude; 1 σ
Position and orientation system	POS AV™ AP50 (OEM)
Sensor range precision (5)	<8 mm, 1 σ
Scan width (FOV)	Programmable, 0-50 degrees
Scan frequency	Programmable, 0-90 Hz
Sensor scan product	1000 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±30° (FOV dependent)
Vertical target separation distance	<0.7 m
Multipulse	Yes
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Data storage	Internal solid state drive SSD (SATA II); Removable SSD (optional)
Image capture	Compatible with Optech CS-Series digital metric cameras
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Recorder (optional)
Gyro-stabilization	SOMAG GSM 3000 integration kit (optional)
Power requirements	28 V; 300 W; 12 A
Dimensions and weight	Sensor: 340 x 340 x 250 mm, 25 kg; PDU: 415 x 328 x 100 mm, 6.5 kg
Operating temperature	0 to +35°C
Relative humidity	0-95% non-condensing

1. Target reflectivity ≥20%.
2. Dependent on selected operational parameters using nominal FOV of up to 50° and Optech LMS Professional software suite in standard atmospheric conditions (i.e., 23 km visibility).
3. Angle of incidence ≤25°.
4. Target size ≥ laser footprint.
5. Under Optech test conditions, 1 sigma.



US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1

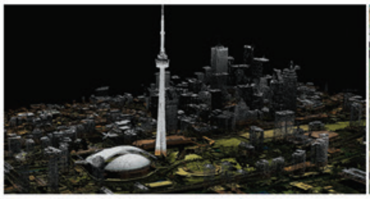
PEGASUS HD500

Summary Specification Sheet

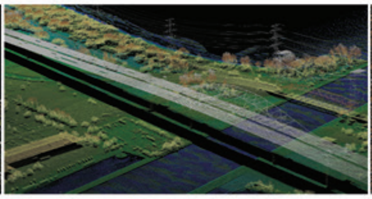
The benchmark in airborne lidar mapping and active imaging technology.

HIGH DENSITY 500 kHz

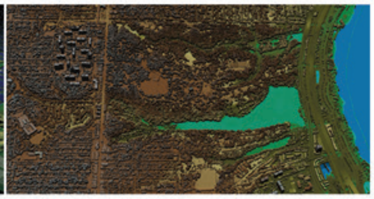
ALTM Pegasus



Urban Modeling



Asset Management



Topographic Mapping

Optech

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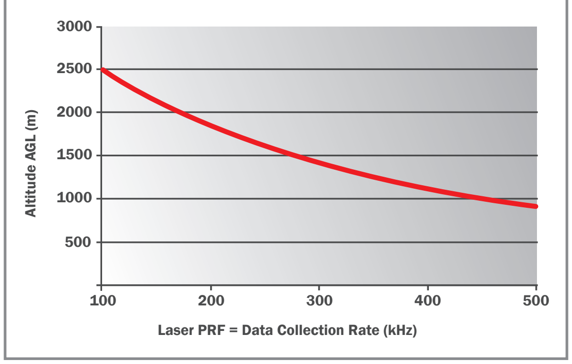
PEGASUS HD500

The ALTM Pegasus Advantage

Pegasus is ideally suited for applications that require maximum collection efficiency in a wide FOV design, while maintaining enhanced target detail and maximum ground density with high range accuracy and precision.

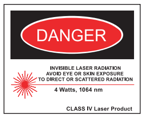
- Dual output laser system for maximum density capability
- High laser sampling rate for enhanced efficiency in XY point distribution
- Extended operating envelope
- "Drop-in" sensor design for unrestricted use of advertised FOV in deep portal installations
- High accuracy and precision independent of pulse rate, enabled by Optech's iFLEX™ technology
- The latest in tightly-coupled inertial and Virtual Reference System processing technology, enabling steep turns, extended GPS baselines, and the elimination of remote base stations
- Powerful Optech LMS lidar pre-processing software with automated lidar rectification

ALTM Pegasus Operating Envelope



Parameter	Specification
Operational envelope [1,2,3,4]	300-2500 m AGL, nominal
Laser wavelength	1064 nm
Horizontal accuracy [2]	1/5,500 x altitude; 1 σ
Elevation accuracy [2]	<5-15 cm, 1 σ
Effective laser repetition rate	Programmable, 100-500 kHz
Position and orientation system	POS AV™ AP50 (OEM) 220-channel dual frequency GPS/GNSS/Galileo/L-Band
Scan width (FOV)	Programmable, 0-75°
Scan frequency [5]	Programmable, 0-140 Hz (effective)
Sensor scan product	800 maximum
Beam divergence	0.25 mrad (1/e)
Roll compensation	Programmable, ±32.5° (FOV dependent)
Vertical target separation distance	<1.0 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	Up to 4 intensity returns for each pulse, including last (12 bit)
Image capture	5 MP interline camera (standard); 60 MP full frame (optional)
Full waveform capture	12-bit Optech IWD-2 Intelligent Waveform Digitizer (optional)
Data storage	Removable solid state disk SSD (SATA II)
Power requirements	28 V, 600 W, 21 A
Dimensions and weight	Sensor: 630 x 540 x 450 mm; 65 kg; Control rack: 650 x 590 x 490 mm; 46 kg
Operating temperature	-10°C to +35°C
Relative humidity	0-95% non-condensing

1 Target reflectivity ≥10%
2 Dependent on selected operational parameters using nominal FOV of up to 50° in standard atmospheric conditions with 24-km visibility
3 Angle of incidence ≤25°
4 Target size ≥ laser footprint
5 Dependent on system configuration



US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1

Optech

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Optech

Optech

Aquarius

Summary Specification Sheet

Features

- Simultaneous land/ water depth mapping capability
- Available as a sensor head addition to the Gemini ALTM or as a complete standalone mapping system
- Software workflow similar to ALTM workflow with Optech LMS
- Drop-in sensor design for small portal aircraft installations

Applications

- Coastal and shoreline mapping
- Bathymetry
- Environmental
- Natural resources

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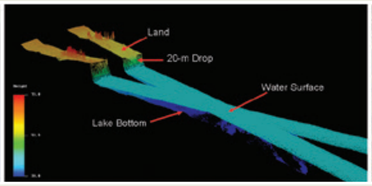
Compact Shallow Water Mapping Sensor

The Optech Aquarius ALTM is an innovative compact solution for mapping coastal and inland waterways. Compatible with the Gemini ALTM system, Aquarius collects simultaneous land and water-depth measurements, enabling wholly complete data sets that span the land/water interface. Designed as a complementary sensor to Optech's full-featured lidar bathymetry systems, Aquarius provides depth information in relatively shallow water environments not previously accessible to conventional topographic mapping sensors alone.

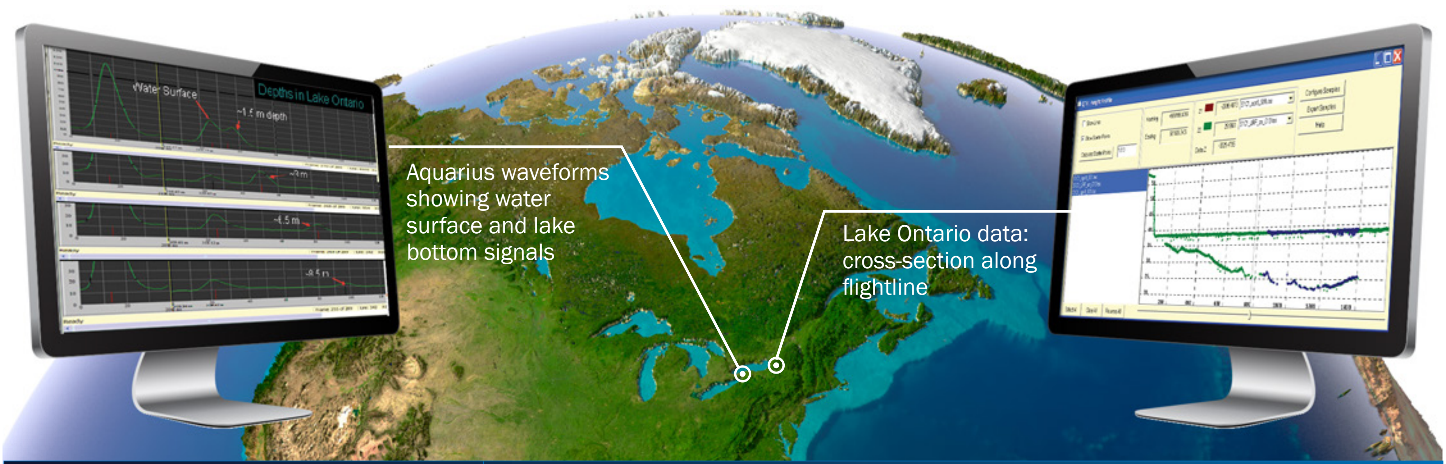
Aquarius Flight Tests



Aquarius Processed Data

Topographic Land Data

The Aquarius Advantage



Parameter	Specification
Shallow water mode	
Operational altitude	300 - 600 m AGL, nominal
Laser pulse repetition rate	33, 50, 70 kHz
Scan rate	0 - 70 Hz
Scan half-angle	0 to ±25°
Laser footprint on water surface	30 - 60 cm
Depth range	0 to >10 m (for k<0.1/m)
Topographic mode	
Operational altitude	300 - 2500 m
Range capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity capture	12-bit dynamic measurement range
Position and orientation system	POS AV™ 510 (OEM) includes embedded 72-channel GNSS receiver (GPS and GLONASS)
Data storage	Ruggedized removable SSD hard disk (SATA II)
Power	28 V; 900 W; 35 A (peak)
Video camera	Internal video camera (NTSC or PAL)
Image capture	Compatible with full line of Optech aerial digital cameras (optional)
Full waveform capture	12 bit IWD-2 Intelligent Waveform Digitizer (optional)
Dimensions and weights	
Control rack (W x H x D)	591 x 485 x 578 mm
Weight	53 kg
Sensor head (W x H x D)	Top: 250 x 430 x 320 mm; Lower: 170 x 280 x 230 mm
Weight	30 kg
Strap-on digitizer	3U rack height
Operating temperature	0-35° C
Relative humidity	0-95% non-condensing

US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1

Optech

Lynx SG1 Mobile Mapper™

Summary Specification Sheet

Features

- Highest scanner speed and point density in the industry—provides dense, uniform data at highway speeds
- Configure system parameters for specific applications while still managing data volume
- Optech LMS workflow designed for high-volume production processing
- Automated boresighting for simplified project operations
- Integrated with up to 4 5-Mpix cameras
- Integrated with Ladybug 360° camera for efficient mapping-grade projects
- Optech LMS lidar rectification for automated adjustments to data

Applications

- Corridor surveys
- Design engineering
- Rail surveys
- Utilities mapping

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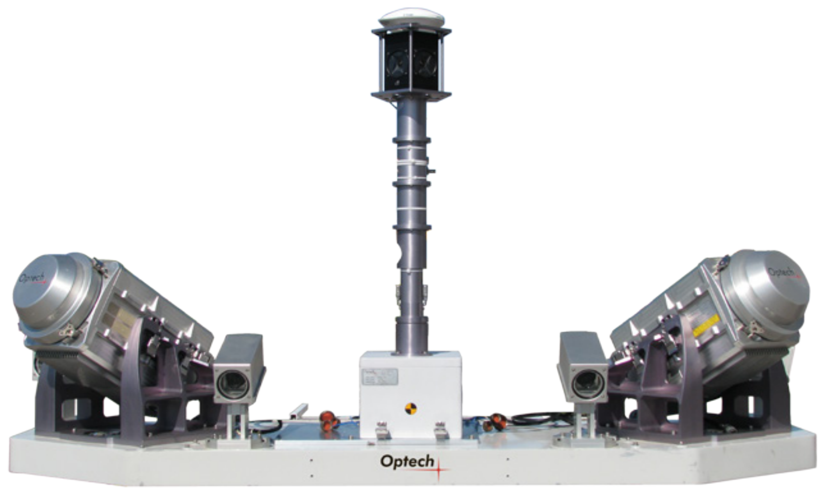
Survey-Grade Lidar Data

The Optech Lynx SG1 mobile lidar system is the best solution on the market for surveying and engineering projects where accuracy, precision and overall cost-effectiveness are paramount. Boasting a measurement rate of 1.2 million measurements per second, a 360° unobstructed field of view, industry-leading scanning speeds of 500 lines/sec (critical for point distribution) and guaranteed survey-grade precision, the Lynx SG1 raises the bar for mobile surveying. The ability to control several integrated cameras, including the Point Grey Ladybug®, positions the Lynx SG1 as the premium choice for mobile surveys where accuracy, precision and resolution are critical.



Premium hardware performance is half of the equation. To ensure maximum return on investment and cost efficiencies, the Lynx SG1 is bundled with a comprehensive software workflow that incorporates Optech LMS Pro.

Optech LMS exists for a single purpose: To maximize the accuracy of collected data while minimizing the cost (in time, dollars and complexity) associated with achieving those results for high-volume production projects. As a result Optech LMS has been designed with speed and automation as a foundation. LMS Pro's lidar rectification process, based on over a decade of research and development, is a breakthrough for both airborne and mobile surveying. Using complex optical and mathematical models, LMS Pro rectifies lidar data files with an accuracy and quality level that require no further refinement—thereby minimizing processing time and maximizing efficiency.

With superior hardware performance and a ground-breaking data processing solution, the Lynx SG1 ensures that even your most challenging projects are delivered on time and on spec.


Road


Rail*


Water**

*Image courtesy of SAM, Inc. ** Image courtesy of WH Pacific Inc.

Optech

Lynx SG1 Mobile Mapper™

The Lynx SG1 Advantage

Overall Lidar Performance

The Lynx SG1 comes with 2 lidar sensors that each boast a 600-kHz measurement rate, 360° FOV, 250-Hz scanner speed and 5-mm precision. The overall Lynx SG1 lidar solution represents the apex in lidar design and performance.

Overall Data Accuracy

Superior sensor performance and automated lidar rectification with Optech LMS Pro generate data accuracies that meet or exceed the requirements of the most difficult projects.

Optech LMS Pro

- Automated lidar rectification algorithms to improve the results of mobile surveys (airborne as well)
- Optional ground control input to lidar rectification algorithms for automated control adjustments
- Automated boresight: Calibration/boresight routines do not require specialized flight/survey regimes
- Batch processing for large, multi-site projects

Camera Options

The Lynx SG1 provides a variety of imaging options designed to meet varying project needs, whether it's a 360° camera, higher-resolution cameras up to 5 Mpix, or a combination of both. If the flexibility is not enough, the system facilitates the addition of auxiliary sensors by making navigation data available.

Software Workflow

Lynx Survey and Optech LMS are a complete software solution that includes best-in-class survey planning, project execution, inertial/positional processing, lidar post-processing, and information extraction.

User-Selectable Scanner Speed

The Lynx SG1 offers programmable scanner speeds up to 250 Hz. The resolution of the resulting lidar point cloud is a function of the measurement rate, vehicle speed and scanner speed. With the industry's best measurement rates and scanner speeds, the Lynx SG1 provides up to a 20% increase in data resolution at 100 km/hr over its closest competitor.

Parameter	Lynx SG1
Number of lidar sensors	2
Camera support (1)	Up to four 5-Mpixel cameras and one Ladybug® camera
Timestamp for additional camera/sensor (2)	Yes
Maximum range (3)	250 m @ 10% reflectivity
Range precision (4)	5 mm, 1 σ
Absolute accuracy (5)	±5 cm, 1 σ
Laser measurement rate	150-1200 kHz programmable
Measurement per laser pulse	Up to 4 simultaneous
Scan frequency (6)	Up to 500 lines/sec programmable
Scanner field of view	360° without obscurations
Power requirements (7)	12 VDC, 40 A max. draw
Operating temperature	-10°C to +40°C (extended range available)
Storage temperature	-40°C to +60°C
Relative humidity	0-95% non-condensing
Laser classification	IEC/CDRH Class 1 eye-safe
Vehicle	Fully adaptable to any vehicle

1 Lidar sensor supports two 5-Mpixel cameras.
2 Customer can add additional sensors and use existing POS output.
3 Slant range from sensor.
4 Under test conditions. Contact Optech for details.
5 Assumes good GPS data (PDOP <4) and 10-m range using a post-processed GPS trajectory. Performance will degrade in the event of poor or lost GPS.
6 Up to 250 lines/sec per lidar sensor.
7 Power during initialization: 12 VDC, 60 A.

TELEDYNE OPTECH
Everywhereyoulook™

Optech Titan Multispectral Lidar System

High Precision Environmental Mapping

Applications

- Topographic mapping
- Land cover classification
- Seamless shallow water bathymetry
- Environmental modeling
- Forest inventory and vegetative classification
- Natural resource management
- Disaster response

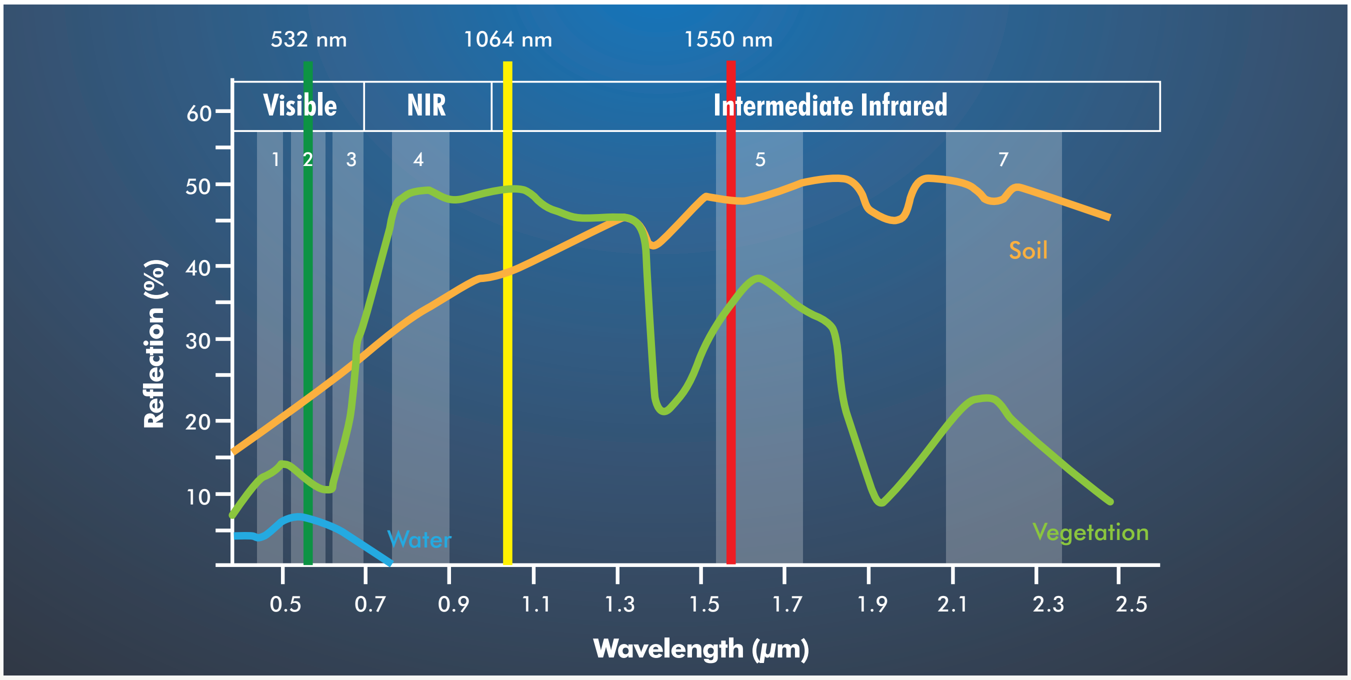
A new era in fused sensor performance and feature identification!

The Optech Titan is the world's first multispectral airborne lidar sensor, a revolutionary sensor that includes three active imaging channels of different wavelengths for day or night mapping of complex environments. Capable of capturing discrete and full-waveform data from all three channels, Titan has a combined ground sampling rate approaching 1 MHz that results in ultra-dense coverage. The sensor includes full gyro-stabilization compatibility and a fully-programmable scanner for significantly boosting point density with narrower FOVs. Passive imagery support is available via fully-embedded high-resolution metric mapping cameras, including multispectral, thermal, NIR and RGB options.

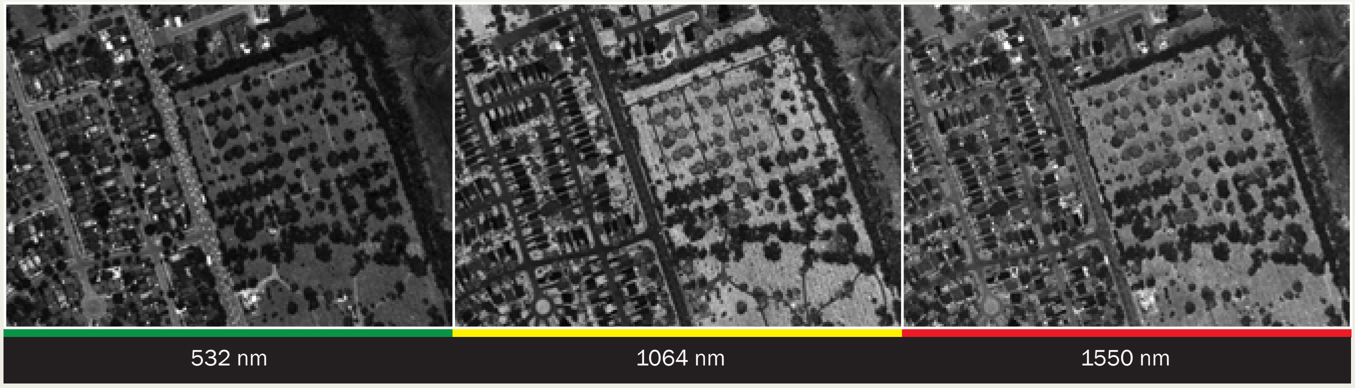
Active multispectral sensing: A revolution for lidar

An extremely versatile sensor, Titan is the first commercial multispectral active imaging sensor that enables a broad spectrum of application capability in a single sensor design. By incorporating multiple wavelengths, Titan is just as capable performing high-density topographic mapping as it is doing shallow water bathymetry, vegetation mapping or even 3D land classification.

Materials such as foliage, asphalt and soil reflect or absorb different wavelengths of light in different ways — foliage strongly reflects near-infrared light but absorbs visible green light, whereas soil responds significantly differently to the same wavelengths. With three independent channels, one for each wavelength, operators can now compare the intensity variations of various surface targets to assist in materials differentiation. No longer is lidar restricted to simple coordinate measurements. Titan opens the door for multispectral active imaging of the environment, day or night.

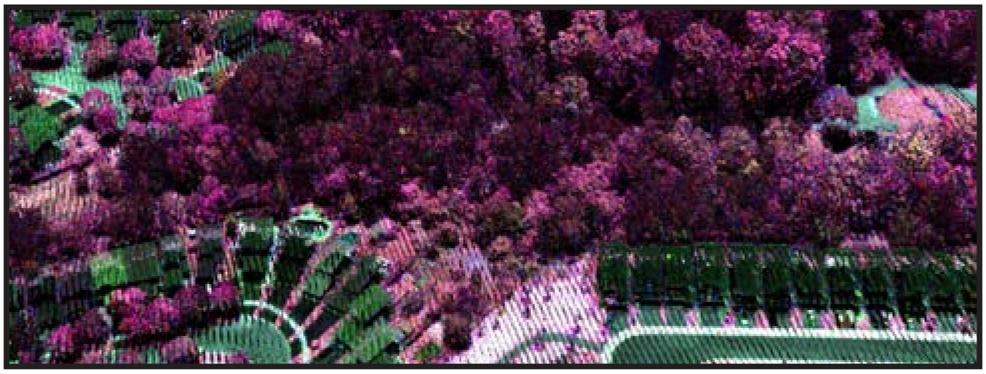


Independent normalized lidar intensity images can be generated for each Titan wavelength



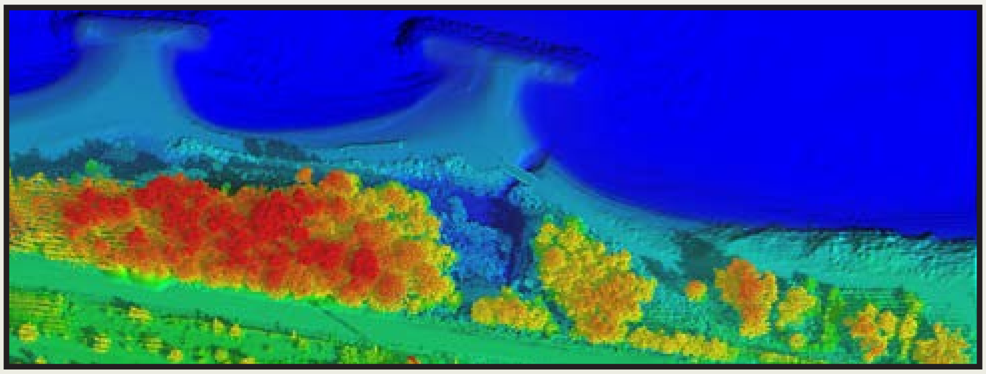
New and improved applications served by Titan include:

3D land cover classification: Significantly improve land cover classification accuracies with 3D multispectral intensity analysis

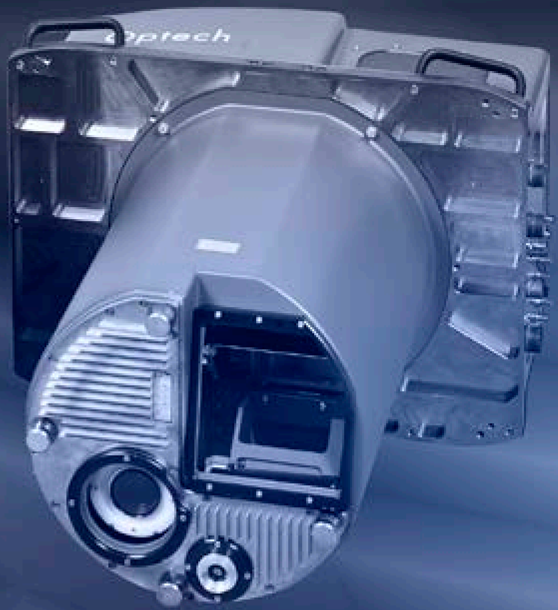


Vegetation mapping: Map vegetative differences for environmental, forestry and agricultural applications day or night, with high precision and accuracy

Shallow-water bathymetry: Collect seamless data sets across the land-water interface with Titan's water-penetrating green channel and surface-detecting NIR channels for shallow water bathymetry



Dense topography: Achieve extreme point density with Titan's 900 kHz pulse repetition frequency, 210 Hz effective scanner rate, and gyro-stabilized sensor configuration



A New Era has Begun!

Titan enables the previously impossible with innovative hardware, software and productivity enhancements

- Three independent active imaging channels that support 532, 1064, and 1550 nm wavelengths for multispectral mapping of the earth's surface, day or night
- A high-resolution "green" channel that ensures high point density for shallow water mapping applications
- Narrow pulse widths, state-of-the-art receiver and timing electronics guarantee the highest range precision possible for maximum data quality
- A fully programmable scanner enables huge increases in point density at narrower FOVs for maximum target resolution and detail over competing sensors
- A 29 MP high-resolution, fully electronic QA camera provides passive imagery support.
- Optional embedded 80 MP RGB orthometric camera with forward motion compensation enhances image quality and improves classification. Also available with imbedded multispectral, thermal or NIR sensor options

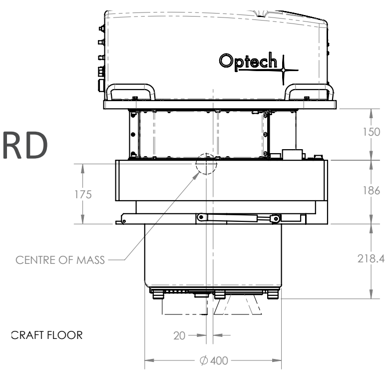
- Realtime XYZI point display, available exclusively with Optech FMS, enables independent channel visualization during flight for true-coverage verification and collection monitoring
- Optional sensor gyro-stabilization, fully automated with Teledyne Optech's comprehensive Flight Management System (FMS) for effortless operation and consistent point distribution
- The latest in tightly-coupled inertial and Virtual Reference System processing technology enables steep turns, extended GPS baselines, and the elimination of remote base stations
- Optional CenterPoint RTX provides global coverage of centimeter-level real time position accuracy, a critical consideration for bathymetric mapping in remote locations (<0.1 m XY)
- Powerful Optech LMS lidar processing software automates sensor calibration, maximizes laser point accuracies and quantifies project accuracy deliverables
- An Optech LMS software extension supports water attenuation corrections for bathymetric applications

TELEDYNE OPTECH
Everywhereyoulook™

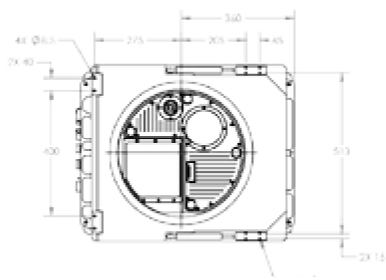
Optech Titan Specifications

Parameter	Specification
Laser Configuration	
Channel 1	1550 nm IR
Channel 2	1064 nm NIR
Channel 3	532 nm visible
Beam divergence	Channel 1 & 2: ≈0.35 mrad (1/e) Channel 3: ≈0.7 mrad (1/e)
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Operating altitudes [1,2]	Topographic: 300 - 2000 m AGL, all channels Bathymetric: 300 - 600 m AGL, 532 nm
Depth performance [1,4]	Dmax (m) ≈ 1.5/K_d, where K_d is the diffuse attenuation coefficient of the water
Effective PRF	Programmable; 50 - 300 kHz (per channel); 900 kHz total
Point density [4]	Bathymetric: >15 pts/m2 Topographic: >45 pts/m2
Scan angle (FOV)	Programmable; 0 - 60° maximum
Effective scan frequency	Programmable; 0 - 210 Hz
Swath width	0 - 115% of AGL
Horizontal accuracy [2,3]	1/7,500 × altitude; 1 σ
Elevation accuracy [2,3]	< 5 - 10 cm; 1σ
Laser range precision [5]	< 0.008 m; 1 σ
Camera Configuration	
Q/A camera	29 MP RGB/CIR; 5.5 µm pixel; 6,600 x 4,400 pixels; 0.5 sec/frame
Medium format camera (optional)	80 MP RGB/CIR; 5.2 µm pixel; 10,320 x 7,760 pixels ; 2.5 sec/frame

STARBOARD



BOTTOM



Optech Titan Specifications *continued*

Parameter	Specification
Sensor Configuration	
Gyro-stabilization	SOMAG GSM3000/4000 compatible (optional)
Roll compensation	Programmable; ±5° at 50° FOV; increasing with decreasing FOV from 50°
Position and orientation system	POSAV AP50 (OEM); 220-channel dual frequency GNSS receiver
Inertial measurement unit	ITAR-free FMU-301 (IMU-46)
Flight management system	Optech FMS with real-time point display
Minimum target separation distance	<1.0 m (discrete)
Range capture	Up to 4 range measurements for each pulse, including last
Intensity capture	Up to 4 range measurements for each pulse, including last 12 bit dynamic measurement and data range
Data storage drives	Removable solid state drive SSD (SATA II)
Waveform capture	12 bit, 1 Gs/sec (optional)
Power requirements	28 V (continuous); 800W (nominal); 30A
Operation temperature	0° to +35°C
Dimensions and weight	Sensor head: 850 x 500 x 680 mm, ≥ 71 kg Control rack: 485 x 535 x 545 mm, ≥ 45 kg

1. *20% reflective surface or bottom.* ***Note:*** *Vegetation and other targets may result in a lower response in the green channel, as compared to the IR channels. Lower operating altitudes may be required to ensure measurable returns from low reflectance targets at 532 nm.*
2. *Dependent on selected operational parameters using nominal 50° FOV in standard atmospheric conditions (i.e. 23 km visibility)*
3. *Valid for 1064 nm and 1550 nm channels on above-water targets only*
4. *Assumes 400 m AGL, 60 m/s aircraft speed, 40° FOV*
5. *Under Teledyne Optech test conditions*

TILTED

REAR

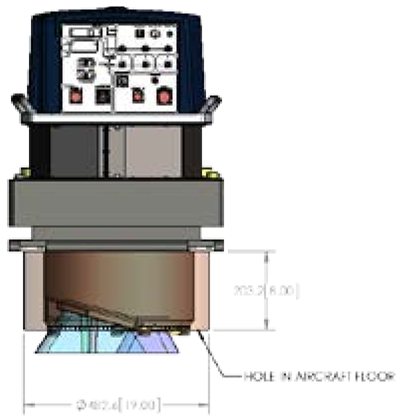


Image courtesy of Laserdata GmbH

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The Optical Society

Elizabeth A. Rogan
Chief Executive Officer

DATE: July 6, 2015

TO: Dennis Krepp, Director, Office of National Security and Technology Transfer Controls, Bureau of Industry and Security, Department of Commerce, and Mr. C. Edward Peartree, Director, Office of Defense Trade Controls Policy, Department of State

FROM: The Optical Society (OSA)

RE: Department of Commerce Regulation Identifier Number (RIN) 0694-AF75 / Department of State RIN 1400-AD32

To whom it may concern:

We are submitting this response to the United States Munitions List (USML) Category XII Proposed Rule Change that was published in the Federal Register on May 5, 2015. The Optical Society (OSA) is the leading professional association representing the optics and photonics technology sectors. The United States Munitions List (USML) Category XII encompasses fire control, range finder, optical and guidance and control equipment that the United States considers critical to national security. The goal of the Category XII proposed rule change was to move dual-use items with both military and commercial applications from the State Department USML list to the less restrictive Commerce Control List (CCL) list. This proposed goal was intended to eliminate regulations and jurisdictional classifications confusion between the USML and CCL.

OSA members produce and develop technologies included in Category XII classification and believe that this rule change increases jurisdictional confusion related to technology classification between the USML and CCL. OSA membership has grave concerns about the implications of this proposed rule were it to go into effect as it would harm the industrial competitiveness of the U.S. optics and photonics industry. The Export Control Reform Initiative was intended to increase interoperability with NATO and other close allies, reduce the current incentives for companies in non-embargoed countries to design out or avoid U.S. origin content and allow the United States Government to focus its resources on items of greater concern. The Optical Society believes these objectives aren't realized in the proposed category XII rule change.

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Founded in 1916, OSA is home to accomplished science, engineering, and business leaders from all over the world. Through world-renowned publications, meetings, and membership programs, OSA provides quality information and inspiring interactions that power achievements in the science of light. OSA represents over 19,000 individual members and 265 businesses. OSA's mission is to promote the generation, application and archiving of knowledge in optics and photonics and to disseminate this knowledge worldwide. The purposes of the Society are scientific, technical and educational. OSA's commitment to excellence and long-term learning is the driving force behind all its initiatives.

President Obama's Export Control Reform (ECR) that began in 2009 was intended to better protect America's most sensitive defense technologies, while at the same time reduce unnecessary restrictions on exports of less sensitive items. This Category XII proposed rule change, rather than reduce unnecessary restrictions on exports of less sensitive items, instead is more complex than the current rule. The proposal would hurt the U.S. optics and photonics industry, including OSA members, in competing with foreign businesses.

The Optical Society represents many small companies in the optics and photonics technology sector that have recently spun off from university-based research and development applications. As with any industry, these small innovative companies represent future technology growth areas and are positioned to grow into larger entities and lead the county and world in commercializing and manufacturing optical and photonics-based technologies in this fast-growing global industry expected to total $47 billion in 2015. Many of these small companies are able to commercialize dual use technologies with the support of federal government research and development programs such as Small Business Innovative Research grants.

Under the proposed rule changes to Category XII these companies in their infancy will be severely disadvantaged by utilizing Department of Defense federal research and development grant funds that will classify the technology they are developing/commercializing as a defense article to be listed on the USML and controlled by ITAR regardless of whether the technology is a sensitive military system or intended also for dual use civilian applications. The Optical Society believes this issue needs to be addressed and revised before any final Category XII rule changes are implemented.

Many foreign competitors advertise themselves as "ITAR-free" as a way to stress the advantage they have over U.S. businesses that face far more restrictive export regulations. As a result, U.S. businesses suffer, and this would only continue in future years if the Category XII proposed rule was implemented. While the goal of Export Control Reform was to build taller walls around fewer controlled items, Category XII actually expands regulatory reach to place more items on the more restrictive USML.

The Optical Society believes that the United States should align its export controls more closely to that of the Wassenaar Agreement. The arrangement is an export control agreement between 41 countries, including the United States, that meet annually to discuss and agree which military and dual-use items should be controlled and which should not. Countries in the agreement then create their own regulations to decide how to best control the agreed upon items. The proposed rules would create a far more restrictive export control system in the United States than what is provided for under the Wassenaar agreement. In turn, this would severely curtail and hurt U.S. competitiveness when a similar product can be purchased from another country without the same restrictions.

The Export Control Reform Initiative also intended to create a simple regulatory definition of "specially designed" criteria. "Specially designed" criteria was defined by the U.S. departments of State and

Commerce in 2013 to speed up the process of determining whether an item is designed for military applications or not. The criteria was then applied to the USML as categories were revised for the Export Control Reform Initiative. OSA is concerned that the Category XII proposed rule does not effectively use the “specially designed” criteria to place products with commercial applications on the CCL, instead leaving them on the more restrictive USML and placing a higher regulatory burden on industry.
OSA is concerned that the Category XII proposed rule will place significant burdens on U.S. businesses competing with foreign companies. Under the proposed rule, companies might not be aware that an item they are developing now falls under the USML and not the CCL, potentially exposing the company to serious penalties. The proposed rule has widespread implications, as it could affect many U.S. companies’ export posture in a negative way related to utilizing Department of Defense funding for research, development and manufacturing optical and photonic technologies independent of utilizing Department of Defense research funding within the United States. The Export Control Reform Initiative was designed to streamline the export process and remove burdensome controls, but instead it creates more confusion. Companies, especially smaller ones without in-house legal counsel, may be hesitant to develop new technologies if export rules are too complex to understand.

The Optical Society, on behalf of its membership, asks that the proposed Category XII rule changes be revised and developed in coordination with additional input from industry, government and university stakeholders. Category XII should implement the “specially designed” criteria to ensure that commercial products are placed on the less restrictive Commerce Control List and not the U.S. Munitions List. Doing so would ensure that the United States is meeting both national security needs as well as enabling industry to better understand regulatory provisions and compete in the global marketplace.

Sincerely,

Elizabeth A. Rogan

Elizabeth Rogan
CEO, The Optical Society

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Submission Type: Web

PUBLIC SUBMISSION

Docket: DOS-2015-0027
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
International Traffic in Arms: U.S. Munitions List Category XII; Revision

Document: DOS-2015-0027-DRAFT-0016
Comment on DOS-2015-0027-0001

Submitter Information

Name: Corey Stewart
Submitter's Representative: Corey Stewart
Organization: Toyota Motor Engineering & Manufacturing North America, Inc.

General Comment

Toyota Motor Engineering & Manufacturing North America, Inc. (TEMA), an U.S. affiliate of Toyota Motor Corporation of Japan, hereby submits its comments with regard to the proposed rule regarding USML Category XII (22 CFR Part 121). The proposed rule should be revised and clarifiedparticularly provisions at paragraphs (c)(2), (c)(6) and the Note to paragraph (b)(6).
The Note to paragraph (b)(6) exempts from ITAR control certain LIDAR systems for civil automotive application. Several other paragraphs of the proposed rule, however, would appear to negate the usefulness of this exemption by placing many of the critical components of LIDAR systems under ITAR control. Because an item containing an ITAR-controlled component is thereby subject to ITAR control itself, this exemption would be limited to only those systems that contain no component listed in Category XII. Because Category XII would control many components that are critical in an effective automotive LIDAR system (especially the IRFPAs discussed below), it would be difficultif not impossibleto construct a LIDAR system effective for automotive safety application that contains no ITAR-controlled component.
The Note to (b)(6) is also unnecessarily restrictive with regard to the range of the LIDAR systems for civil automotive applications. For automotive safety purposes, enhancing the range of the LIDAR means providing the driver with greater potential response time. TEMA understands that LIDAR systems for automotive application with ranges in excess of 200 meters are already under development. We suggest revising this restriction to 400 meters.
In order of preference, TEMA respectfully suggests either of the following alternatives to the Note to (b)(6):
Alternative 1: Exclude from ITAR control LIDAR components designed for civil automotive LIDAR systems:
Note to paragraph (b)(6): This paragraph Category XII does not control LIDAR Systems,

components or parts of such Systems, or equipment for civil automotive applications.
Alternative 2: Exclude from ITAR control LIDAR components designed for civil automotive LIDAR systems having a range limited to 400 meters or less.
Note to paragraph (b)(6): This paragraph Category XII does not control LIDAR Systems, components or parts of such Systems, or equipment for civil automotive applications having a range limited to 200 400 m or less.
TEMA also requests revision of Paragraphs (c)(2) and (c)(6). These paragraphs would effectively preclude the incorporation of an Infrared Focal Plane Array (IRFPA) into an automotive LIDAR system. For civil collision avoidance, a LIDAR system must be able to detect and track distant objects in real time. To do so, a LIDAR needs high spatial resolution and wide coverage in a short time period (fast update rate) while the vehicle is in motion. An IRFPA is uniquely capable of achieving this performance by using time-of-flight (TOF) to instantaneously create a 3D depth map.
Together, paragraphs (c)(2) and (c)(6) would control IRFPAs with a wavelength between 900 nm and 30,000 nm. This limitation would preclude the use of IRFPAs for automotive application since, as noted below, all wavelengths potentially useful for automotive application fall within that range:
1400-1600 nm Detection of automobiles and other objects
30005000 nm Penetration of mist, dust, smoke and other small particles
1000015000 nm Detection of persons and live animals
Wavelengths below 1400 nm are not eye-safe and those above 15,000 nm are insufficiently intense for any automotive safety application.
Additionally, paragraphs (c)(2) and (c)(6) should be revised since the IRFPAs that would be controlled thereunder are already available internationally, including the following: (i) Chunghwa Leading Photonics Tech. (Taiwan) InGaAs FPA 320 x 256 (Exhibit 1); and (ii) Xenics (Belgium) InGaAs XFPA-1.7-640-LN2 (Exhibit 2).
In order of preference, TEMA respectfully suggests either of the following alternatives with regard to paragraph (c)(2):
Alternative 1: Revise Note 1 to paragraph (c)(2) to include the following:
IRFPAs used in automotive LIDAR systems are not subject to the ITAR.
Alternative 2: Revise (c)(2) to control only those IRFPAs specially designed for military application, as follows:
(c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) specially designed for military application , , ,.
Finally, TEMA requests revision of paragraph (c)(12)(viii), which would control certain photon detector IRFPAs with a resolution exceeding 111,000 detector elements. This standard is already outdated, as the standard video graphics array (VGA) is currently 307,200 pixels. TEMA does not yet know the optimal resolution of an IRFPA in a production automotive LIDAR system, but to avoid hindering automotive safety research, we believe the restriction should be set no lower than 327,680 (640 x 512) detector elements.

Attachments

Toyota Comments to USML Category XII (RIN 1400-AD32)

Exhibit 1 - Chunghwa DM-FPA 320x256-C (Taiwan)

Exhibit 2 - Xenics XSW-640 (Belgium)

TOYOTA

Toyota Motor Engineering &
Manufacturing North America
25 Atlantic Avenue
Erlanger, KY 41018-3151

C. Edward Peartree
Director
Office of Defense Trade Controls Policy
U.S. Department of State
Directorate of Defense Trade Controls
2401 E Street, NW, SA-1, Room H1200
Washington, DC 20522-0112

RIN: 1400-AD32
Re: Public Submission Concerning Category XII of USML (22 CFR Part 121)

Dear Mr. Peartree,

In reference to RIN 1400-AD32, Toyota Motor Engineering & Manufacturing North America, Inc. ("TEMA"), an U.S. affiliate of Toyota Motor Corporation of Japan, hereby submits its comments with regard to the proposed rule regarding Category XII of the United States Munitions List ("USML") (22 CFR Part 121). The proposed rule should be revised and clarified—particularly provisions at paragraphs (c)(2) and the Note to paragraph (b)(6) of Category XII.

Toyota engages in automotive safety research and is interested and invested in LIDAR and infrared focal plane array ("IRFPA") technologies for reducing traffic accidents and fatalities. We feel that the proposed rule may not accurately address the needs of private commercial development and, in turn, may hinder important automotive safety research.

1. Note at (b)(6) Needs Clarification and Revision
   The Note at paragraph (b)(6) of the proposed rule excludes from ITAR control certain LIDAR systems for civil automotive applications. While this exclusion is vital to assuring continued automotive safety innovation using LIDAR systems, several other paragraphs of the proposed rule appear to severely limit the usefulness of this exclusion by placing many of the critical components of LIDAR systems under ITAR control, including the following:

Inconsistent Paragraph	LIDAR Component to be Controlled
Cat. XII (b)(8)(iii)	Certain Geiger-mode detector arrays
Cat. XII (c)(2)	Certain photon detector, microbolometer detector, and multispectral detector infrared focal plane arrays
Cat. XII (c)(3)	Certain one-dimensional photon detector IRFPAs
Cat. XII (c)(4)	Certain two-dimensional photon detector IRFPAs
Cat. XII (c)(6)	Certain multispectral IRFPAs

Cat. XII (c)(12)	Certain infrared imaging camera cores
Cat. XII (e)(4)	Certain readout integrated circuits ("ROICs")
Cat. XII (e)(5)	Certain ROICs

a. The Exclusion at the Note to (b)(6) is Inadequate

Because an item containing an ITAR-controlled component is thereby subject to ITAR control itself, the exclusion contained at the Note to (b)(6)—while purporting to exclude LIDAR systems for automotive application—would be limited to only those systems that do not contain any of the components listed in Category XII. Because the list of LIDAR components controlled under Category XII is extensive, it would be difficult—if not impossible—to construct an effective LIDAR system for automotive safety application that contains no ITAR-controlled component. As a result, the exclusion at the Note to (b)(6) is of limited use.

b. 200 Meter Range Limitation is Unnecessarily Restrictive

The exclusion at the note to paragraph (b)(6) is, in addition, unnecessarily restrictive with regard to the range of the LIDAR systems for civil automotive applications. For automotive safety purposes, enhancing the range of the LIDAR means providing the driver with greater potential response time. TEMA understands that LIDAR systems for automotive application with ranges in excess of 200 meters are already under development. We would therefore suggest revising this restriction to 400 meters.

c. Alternative Language: Note to (b)(6)

In order of preference, TEMA respectfully suggests either of the following alternatives to the Note to paragraph (b)(6):

Alternative 1: Exclude from ITAR control LIDAR components designed for civil automotive LIDAR systems:

"Note to paragraph (b)(6): ~~This paragraph~~ <u>Category XII</u> does not control LIDAR Systems, <u>components or parts of such Systems</u>, or equipment for civil automotive applications."

Alternative 2: Exclude from ITAR control LIDAR components designed for civil automotive LIDAR systems having a range limited to 400 meters or less.

"Note to paragraph (b)(6): ~~This paragraph~~ <u>Category XII</u> does not control LIDAR Systems, <u>components or parts of such Systems</u>, or equipment for civil automotive applications having a range limited to ~~200~~ 400 m or less."

2. <u>Paragraph (c)(2) Overly Broad</u>

Paragraph (c)(2) is, in particular, overly broad and would hinder automotive safety research using LIDAR systems. This paragraph—which controls multispectral IRFPAs having a wavelength between 1,500 nm and 30,000 nm—would effectively preclude the incorporation of any IRFPA into an automotive LIDAR system.

a. IRFPA Critical Component of Automotive LIDAR System

To be effective for civil collision avoidance, a LIDAR system must have the capability to detect and track distant objects in real time. To do so, a LIDAR needs high spatial resolution and wide coverage in a short time period (fast update rate) while the vehicle is in motion. An IRFPA is uniquely capable of achieving this performance by using time-of-flight ("TOF") to instantaneously create a 3D depth map.

b. Wavelength Limitation Precludes Automotive Safety Application

Paragraph (c)(6) would control IRFPAs with a wavelength between 900 nm and 30,000 nm. This limitation would effectively preclude the use of IRFPAs for automotive application since, as the table below demonstrates, all wavelengths potentially useful for automotive application fall within that range:

Approximate Wavelength Range (in *nm*)	Automotive Application
1,400 – 1,600	Detection of automobiles and other objects
3,000 – 5,000	Penetration of mist, dust, smoke and other small particles
10,000 – 15,000	Detection of persons and live animals

Other wavelength ranges that would not be controlled under the proposed rule would be of no use for automotive safety application. Wavelengths below 1400 nm are not eye-safe and those above 15,000 nm are insufficiently intense for any automotive safety application.

c. Wide Foreign Availability

The international market for IRFPAs has grown immensely over the past several years. IRFPAs that would be controlled under (c)(2) are now widely available abroad, including the following:

IRFPA	Wavelength Range (in *nm*)	Manufacturer	Country
InGaAs FPA 320 x 256 (**Exhibit 1**)	900 – 1700	Chunghwa Leading Photonics Tech.	Taiwan
InGaAs XFPA-1.7-640-LN2 (**Exhibit 2**)	850 – 1600	Xenics	Belgium

d. Alternative Language: Paragraph (c)(2)

In order of preference, TEMA respectfully suggests either of the following alternatives with regard to paragraph (c)(2):

Alternative 1: Revise Note 1 to paragraph (c)(2) to include the following: ***"IRFPAs used in automotive LIDAR systems are not subject to the ITAR."***

Alternative 2: Revise (c)(2) to control only those IRFPAs specially designed for military application, as follows:

"(c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) specially designed for military application and having

a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor."

3. <u>Resolution Restriction in Paragraph (c)(12)(viii) is Outdated</u>
   Paragraph (c)(12)(viii) would control certain photon detector IRFPAs with a resolution exceeding 111,000 detector elements. This standard is already outdated, as the standard video graphics array ("VGA") is currently 307,200 pixels. TEMA does not yet know the optimal resolution of an IRFPA in a production automotive LIDAR system, but to avoid hindering automotive safety research, we believe the restriction should be set no lower than 327,680 (640 x 512) detector elements.

4. Point of Contact
   If you require additional information, please contact Mr. Corey Stewart, who is authorized to interact with the U.S. government on TEMA's behalf, as follows:

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corey.stewart@stewartpllc.com

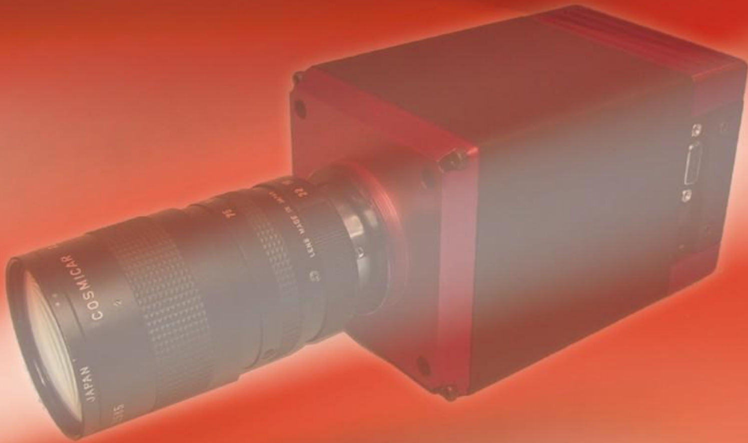
* * *

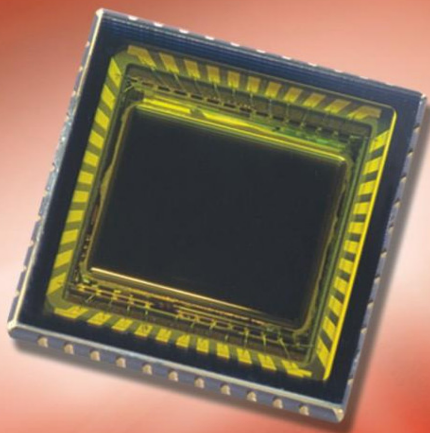
Thank you for the opportunity to comment on the proposed rule. Please let us know if we can be of any assistance as you consider this important matter.

Respectfully Submitted,

David Stanley
Manager – Trade Compliance
Logistics Control
Parts Business Management

http://www.leadinglight.com.tw/





InGaAs FPA 320x256

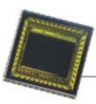
The InGaAs focal plane array is the optimized solution for near-infrared imaging and imaging spectrography applications in 900nm to 1700nm wavelength range especially under uncooled condition. The core technology of CLPT implements the InGaAs FPA with excellent quality. The CLCC package also facilitates the mechanical design of CCD and CMOS camera vendors.

Features

- 320x256 array format
- 30um pixel pitch
- CLCC package
- Low dark current
- High quantum efficiency
- High operability

Applications

- Near-infrared imaging
- Hyper spectrum
- Covert surveillance
- Semiconductor inspection
- Astronomy and scientific
- Industrial thermal imaging



中華電信股份有限公司
Chunghwa Telecom Co., Ltd.

中華立鼎光電
Chunghwa Leading Photonics Tech.

InGaAs FPA 320x256

Specifications of FPA 320x256-C

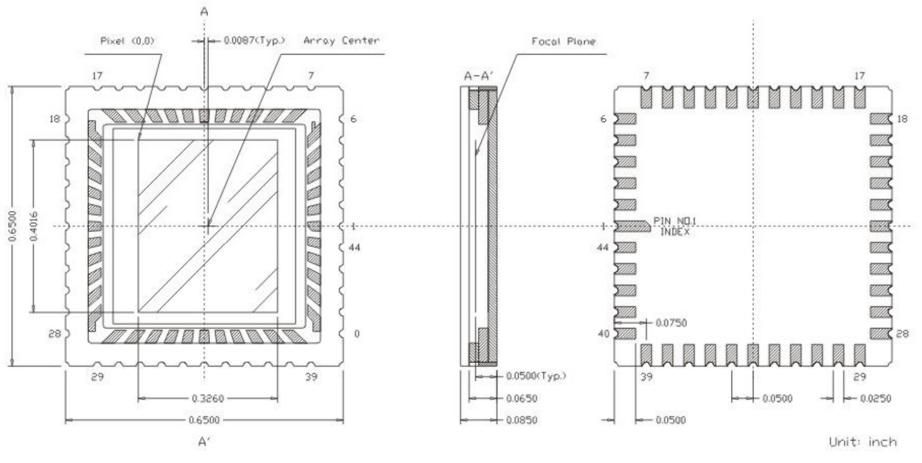
Absolute Maximum Ratings

Parameter	Unit	Min	Max
Operation Temperature	°C	-20	85
Storage Temperature	°C	-40	85
Power Consumption	mW	---	175

FPA Characteristics

Parameter	Typical	Conditions
Spectral response	0.9um-1.7um	---
Minimum Pixel Operability	>99%	Within 318x254 center region
Dark current	<0.4pA	25°C,0.1V detector bias
Quantum efficiency	>70%	λ =1.0um-1.6um
Detectivity	≧5x10[11] Jones	25°C, λ =1.55um, T_{int}=16ms,High Gain
Response nonumiformity	<10%	under 50%saturation,25°C
Nonlinearity(max.deviation)	<2%	Over 10%-90% full well capactity
Max.pixel rate	10MHz	---
GAIN	High:14.38uV/e^- Low:0.77uV/e^-	25°C

Package Outline



中華立鼎光電
Chunghwa Leading Photonics Tech.

Chunghwa Leading Photonics Tech.
Address: 12, Lane 551, Min-Tsu Road Sec. 5, Yang-Mei, Taoyuan, Taiwan 32617, R.O.C.
Tel: +886-3-4244050/Fax: +886-3-4245849
E-mail: cchong@cht.com.tw
http://www.leadinglight.com.tw/

Xenics
Infrared Solutions

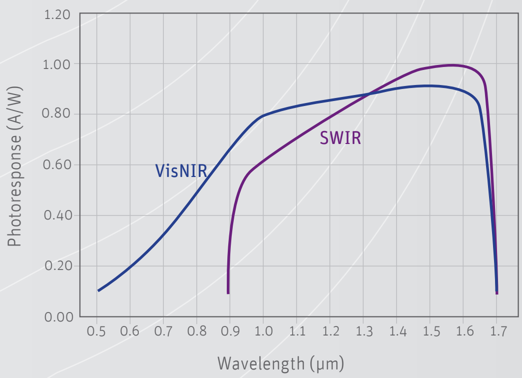
Imagine the invisible

Modules & components

XSW-640

High resolution
TE1-stabilized SWIR OEM module

Ready-to-integrate SWIR OEM module consuming ultra-low-power



Xenics' XSW-640 OEM module is extremely compact and versatile for easy and swift integration in your SWIR imaging configuration.

Typical OEM applications include infrared imaging for man–portable and unmanned (airborne and land-based) vehicle payloads, night vision, border security, Search & Rescue (SAR) and more.

The XSW-640 OEM module detects short wave infrared radiation between 0.9 (optionally 0.4) and 1.7 μm with a wide dynamic range and wide operating temperature.

The Thermo Electric (TE) stabilization reduces the dark current and noise levels. Together with on-board image processing you will have best contrast and high image quality.

Designed for use in

Person identification

Camouflage detection

Vision enhancement: looking through haze with SWIR

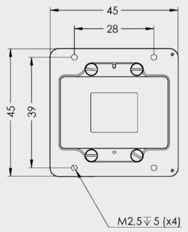
Key features

- Made in Europe
- High resolution
- Easy connectivity
- Small 20 μm pixel pitch

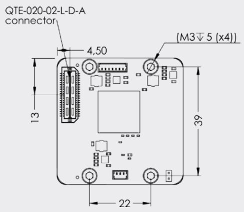
OEM applications

- SWIR sights
- UAV / UGV
- Border security
- Laser detection
- Night vision (passive & active)
- Search & Rescue
- Driver assistance
- Electro optical payloads
- Long range identification
- Enhanced Vision Systems (EVS)

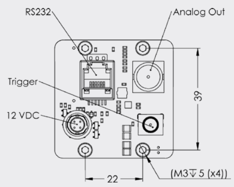
Ready-to-integrate



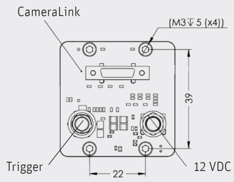
Front of module



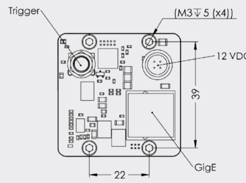
Samtec QTE interface



Analog interface



CameraLink interface



GigE interface

Specifications

Module specifications	XSW-640-Samtec	XSW-640-Analog	XSW-640-CL	XSW-640-GigE
Lens				
Focal length	Broad range of lenses optional available			
Optical interface	Fixation holes for multiple lens mount			
Imaging performance				
Frame rate	Max 100 Hz	25 Hz (PAL) 30 Hz (NTSC)	Max 100 Hz	
Window of Interest	Minimum size 32 x 4			
Exposure time range	1 µs - 40 ms in high gain mode			
Noise*	High gain: 120 e- Low gain: 400 e-			
Gain	High gain mode: 1.28 e-/ADU Low gain mode: 16.2 e-/ADU			
On-board image processing	Image correction (TrueNUC for high gain and low gain), auto gain, auto exposure, histogram equalization, trigger possibilities			Up to 4 NUCs, auto gain, trigger possibilities
ADC	14 bit			
Interfaces				
Digital output	BT.601-6/ BT.656-5	-	CameraLink or Xeneth API/ SDK	GigE Vision or Xeneth API/SDK
Analog output	-	PAL or NTSC	-	-
Module control	Serial LVCMOS 3 V (XSP)	RS232 (XSP)	CameraLink	GigE Vision
Trigger	In or out (configurable)			
Power requirements				
Power consumption* (without TEC)	2.5 W	3 W	2.8 W	4 W
Power supply	+/- 12 V			
Physical characteristics				
Shock	40 G, 11 ms halfsine profile, according to MIL-STD810G			
Vibration	5 G, (20 Hz to 1000 Hz), according to MIL-STD883J			
Operating case temperature	-40 °C to 70 °C (industrial components)			
Storage temperature	-45 °C to 85 °C (industrial components)			
Dimensions (W x H x L mm³)	45 x 45 x 51	45 x 45 x 55	45 x 45 x 55	55 x 55 x 65
Weight module (without lens)	120 g	145 g	129 g	165 g

** Typical values*

Array specifications	XSW-640
Sensor type	InGaAs Focal Plane Array (FPA) ROIC with CTIA** topology
Spectral band	0.9 to 1.7 µm Optional 0.4 to 1.7 µm (VisNIR)
# pixels	640 x 512
Pixel pitch	20 µm
Readout mode	Integrate Then Read (ITR) Integrate While Read (IWR)
Quantum efficiency	80 % @ 1.6 µm (SWIR) 85 % @ 0.9 µm (VisNIR)
ROIC noise*	High gain: 60 e-; low gain: 400 e-
Sensitivity*	High gain: 20 µV/e-; low gain: 1.6 µV/e-
Dark current*	0.8 x 10⁶ e-/s
Integration capacitor	High gain: 6.7 fF; low gain: 85 fF
Array cooling	TE1-stabilized
Pixel operability	> 99 %

** Typical values*
*** Capacitor TransImpedance Amplifier*

Product selector guide

Part number	Frame rate	Interface	VisNIR
XEN-000295*	100 Hz	16bitDV	No
XEN-000304**		BT.656	
XEN-000343		CameraLink	
XEN-000341		GigE Vision	
XEN-000347	25 Hz	PAL	
XEN-000348	30 Hz	NTSC	
XEN-000098*	100 Hz	16bitDV	Yes
XEN-000305**		BT.656	
XEN-000344		CameraLink	
XEN-000342		GigE Vision	
XEN-000349	25 Hz	PAL	
XEN-000350	30 HZ	NTSC	

Part number	Interface	Connects with	Optional
ASY-000880*	CameraLink	XEN-000295 XEN-000098	Yes
ASY-000879**	PAL/NTSC	XEN-000304 XEN-000305	

** and ** Optional test board interface*

www.xenics.com
www.sinfrared.com

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T +32 16 38 99 00 • sales@xenics.com

Xenics Infrared Solutions
ISO 9001:2008 certified

July 6, 2015

PUBLIC DOCUMENT

Submitted electronically to DDTCPublicComments@state.gov

U.S. Department of State
PM/DDTC, SA-1, 12th Floor
2401 E Street, NW
Washington, D.C. 20037

ATTN: Mr. C. Edward Peartree, Director, Office of Defense Trade Controls Policy

Subject: RIN 1400–AD32; ITAR Amendment – Category XII

Dear Mr. Peartree:

Umicore USA, Inc. ("Umicore USA"), its parent N.V. Umicore S.A. of Belgium, and its domestic subsidiary Umicore Optics Materials USA Inc. ("UOM"), collectively "Umicore," respectfully submit these comments in response to the May 5, 2015 notice of proposed rulemaking published by the U.S. Department of State, Directorate of Defense Trade Controls ("DDTC") concerning optics equipment. See "Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII," 80 Fed. Reg. 25821 (May 5, 2015).[1]

DDTC specifically requested comments on whether this proposed rule would inadvertently control items on the U.S. Munitions List ("USML") that are in normal commercial use. DDTC also asked the public to identify proposed control criteria that do not clearly describe defense articles or establish a "bright line" between the USML and the Commerce Control List ("CCL"). As a leading global manufacturer in optics materials and products, Umicore is well-positioned to address these questions.

As currently proposed, the new controls for infrared lenses in USML Category XII(e)(9) would be a step in the wrong direction for export control reform. To be clear, Umicore agrees with the decision to exclude optics blanks from ITAR controls; those unfinished optics products do not provide any unique military advantage. However, the proposed regulation would, for the first time, explicitly add infrared lenses to the USML. Infrared lenses, which are mechanical, non-sensing components, and which are widely available from foreign producers at equivalent or better performance capabilities than U.S. products, should be entirely subject to Commerce jurisdiction. Further, there is no reason to default to "specially designed" catch-all controls for infrared lenses. It is possible to establish specific parameters indicating clear military application for infrared lenses to be controlled in the proposed new ECCN 6A615.c on the CCL.

[1] Umicore separately is providing comments on the U.S. Commerce Department's corresponding proposed rulemaking concerning revisions to the CCL, Category 6, which also impacts optics products.

Umicore's comments provide information about the commercial infrared optics industry, explain why infrared lenses should not be controlled under the ITAR, and suggest alternative control parameters for consideration.

I. Company Background

Umicore is a multinational materials company headquartered in Belgium, with more than 14,000 employees in 38 countries. The company's main divisions include energy materials (specialized metals and products for industrial use), performance materials (precious metals and zinc), catalysis (automotive catalysts and precious metals chemistry), and recycling of precious metals and other specialized materials. Umicore's products supply a range of industries, including the automotive, vision, electronics, construction, optics and displays, battery and power distribution, and chemical industries, among others.

Umicore USA, located in Raleigh, North Carolina, is the U.S.-based subsidiary of Umicore. Umicore USA holds UOM, located in Quapaw, Oklahoma, which is the leading U.S. manufacturer of germanium products. The Quapaw facility also performs high volume assembly of infrared imaging products made from GASIR, Umicore's proprietary germanium-based chalcogenide glass. UOM's main markets are thermal imaging and opto-electronic applications, for which it supplies germanium wafers and blanks, infrared germanium and chalcogenide lenses and optics, and germanium-based chemicals. End-use applications for Umicore's infrared products include automotive, thermal imaging, security and surveillance, fire-fighting, defense, and many other commercial and dual-use applications.

Through its U.S. subsidiaries, Umicore provides many high tech engineering and manufacturing jobs within the United States. Umicore's U.S. operations compete on a global basis and derive a substantial and growing portion of their revenue from export-based sales. Umicore expects exports from the United States to increase. However, this rulemaking could have a significant impact on the company's incentives to grow its U.S. operations. Umicore's technology is predominantly E.U.-origin, with technology transfers and production capabilities generally provided from the foreign parent to the U.S. operations. If restrictive unilateral controls apply to optics technology and products within U.S. jurisdiction, which do not apply in the E.U. export control regime, companies like Umicore that also have production facilities in Europe may need to reevaluate their United States growth strategies.

II. Commercial Market for Optics Blanks and Infrared Lenses

When thermal imaging technology first emerged, it primarily was used in experimental science, military, and space applications. However, the past few decades have seen a surge in the development of this technology, along with increasing demand for commercial applications.

Furthermore, the infrared optics industry is now global. The technology and production capabilities required to manufacture high performance infrared optics are not unique to the United States. (In fact, in Umicore's case, the company has transferred technology and production capability from its E.U. operations to the United States.) Therefore, it is imperative that U.S. producers be permitted to export their infrared optics products on the same terms that apply to competitors in foreign jurisdictions, in order to remain viable in the competitive global market. Like the current version of the USML, infrared lenses are not explicitly listed on the Wassenaar Munitions List or the E.U Common Military List.[2]

The following summarizes the current state of the global infrared optics markets.

- The cost of infrared detectors (the most significant component in a thermal imaging system) is dramatically decreasing, which puts pressure on the price of other components such as lenses. With a lower price point, high performance infrared optics products are increasingly accessible for common commercial applications. And, as a corollary, U.S. optics producers need access to commercial customers to increase sales volumes and remain competitive at lower price points.

- Infrared technology is rapidly moving towards smaller systems with higher resolution. For example, the commercial market is now demanding a pixel size of 12 μm (for example, consumer smart phones), with video graphics array (VGA) resolution of 640 x 480 pixels (for example, civilian security/surveillance applications). Industry research predicts that by next year, every key player in the thermal imaging industry will be selling products within the 12 μm pixel range.

- Global competition is increasing, and U.S. optics producers comprise less than half of the total market. Chinese producers are improving the quality of their mass produced germanium-based optics products. China is now producing germanium optics blanks larger than 5 inches wide, as well as infrared lenses with pixels at or below 12 μm, XVGA resolution (1024x768 pixels), and focal lengths exceeding 100 mm. Further, Chinese producers have access to low cost germanium sourced locally, giving them a competitive edge in infrared optics production. Other countries with infrared optics technology and production capabilities at or exceeding the level of the United States include Belgium, Canada, France, Germany, India, Israel, Japan, Korea, Lithuania, Russia, Singapore, Sweden and United Kingdom.

- Well-established commercial markets for infrared optics, which presently use lenses that could be interchangeable for use in military applications, include:
  - Industrial and scientific thermography;
  - Building and construction monitoring and maintenance;
  - Surveillance and security;
  - Automotive safety;
  - Aviation navigation;
  - Maritime navigation;
  - Fire-fighting;
  - Hunting and hobby gun shooting; and
  - Consumer smartphone applications.

- The commercial segment now dominates the uncooled infrared optics industry, with that trend predicted to increase.[3] Umicore estimates that within the next four years, military

[2] The E.U. Common Military List follows the Wassenaar Munitions List, in that they both control infrared and thermal imaging equipment in their respective Category 15, without a specific reference to lenses or other optics components.

end uses for uncooled infrared optics will comprise only 25% of the global market, with commercial applications accounting for the remaining 75%. Of the commercial segment, Umicore expects that consumer applications will be the largest share.

- While large infrared optics elements historically have been used predominantly in military applications, military end users increasingly are requiring smaller size optics for vehicle and soldier-mounted devices. Conversely, civilian space research applications require larger lenses for high powered telescopes. Physical size no longer is a bright-line differentiator between military and commercial applications.

For graphic illustrations showing the market shares for commercial versus military applications, please refer to the charts appended to these comments. Additionally, for detailed information on actual foreign availability of optics products that match or exceed the performance of U.S. produced products, please see the list following the appended charts.

III. Comments on Proposed Rulemaking

Umicore provides the below comments with respect to the proposed rulemaking's impact on infrared lenses. Because Umicore specializes in the production of germanium and chalcogenide,[4] these comments focus on infrared lenses made of those specific materials. Also, these comments do not address optics blanks, since those products are not included in the proposed new USML Category XII. (Umicore is submitting comments to the Commerce Department's parallel rulemaking, which includes optics blanks.)

A. Infrared Lenses Do Not Provide a Unique Military Advantage

The United States does not have a unique military or intelligence advantage with respect to lens technology or production – the rationale stated in the proposed rulemaking for keeping products on the USML. As noted above, Umicore's technology and production process used in manufacturing infrared lenses within the United States are E.U.-origin, transferred from the foreign parent to the U.S. operations. Moreover, this technology and production capability already is global, with China, Israel, and Russia producing comparable infrared lenses and competing to supply orders placed by thermal imaging customers in the United States and Europe. U.S. production of military grade uncooled infrared optics comprises less than half of the global market for that product segment. Increasing the restrictions on infrared optics will drive the global market away from U.S. producers, as customers easily are able to buy "ITAR-free" optics from foreign sources. This will have a devastating effect on the U.S. optics industry, as U.S. production loses its competitive advantage, and companies move optics production (and high tech jobs) overseas.[5]

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[3] Note: uncooled infrared technology can be commercial, dual-use, or military, whereas cooled infrared is still predominantly military.

[4] A chalcogenide glass is a glass containing one or more chalcogenide elements (not counting oxygen). Typically these glasses include sulfur, selenium or tellurium in combination with germanium, arsenic or antimony.

[5] As stated by former Secretary of Defense Robert Gates, in launching the export control reform initiative: "Multinational companies can move production offshore, eroding our defense industrial base, undermining our control regimes in the process, and not to mention losing American jobs. Some European satellite manufacturers

Additionally, infrared lenses are not the "crown jewels"[6] that are the basis for maintaining the United States' military technology advantage. Unlike most items covered under this proposed rulemaking, infrared lenses are not sensors, nor are they systems or equipment containing sensors. Rather, infrared lenses simply are solid discs made of crystalline materials or glass that have the capacity to transmit infrared radiation while filtering out visible light, and which have been optically worked (meaning shaped with curvature), polished, and coated. The infrared transmission is a physical property of the material from which the lenses are made, which can be adjusted or enhanced through the shaping of the material, as well as the application of special coatings to the surface of the material, during the lens finishing process. There is nothing electronic or sensing about how the lenses work; infrared waves just pass through them.

To the extent that these passive components do require export control, the U.S. government can do so effectively through the CCL, including through clear control parameters that could be integrated into the new 600 series for Category 6.

B. Infrared Lenses Should Be Controlled According to Specific Parameters

To the extent that these products could be controlled for reasons other than EAR99, it would be because they can in some instances have certain properties or characteristics that make them particularly useful for military application. On that basis, some lenses and assemblies have been captured by USML Category XII(e), which controls parts and components specially designed for use in military fire control, range finder, optics, and guidance control systems, with the default being that these products generally are EAR99.

If lenses and assemblies are to be explicitly export controlled, they should be regulated according to specific technical parameters. There is no need to resort to the "specially designed" catch-all approach in controlling infrared lenses, given the availability of criteria for distinguishing lenses that are uniquely military in their application. To the extent that certain characteristics and customizations can make an infrared lens predominantly useful in military applications, such lenses should be controlled according to those criteria under the 600 series of the CCL, not the ITAR.

There are several technical criteria that could be useful in determining which lenses should be export controlled versus those that remain EAR99. First, infrared lenses should not be subject to restrictive controls on the basis of their size alone, as size no longer provides a bright line between military and commercial applications. The infrared lens market has reached a place where many customers – including military and commercial – prefer to design their devices around standard catalog parts that increasingly are dual-use. Furthermore, the trend in military applications is towards smaller lenses for vehicle and soldier-mounted devices, while civilian

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even market their products as being not subject to U.S. export controls, thus drawing overseas not only potential customers, but some of the best scientists and engineers as well." Statement available online at: http://www.defense.gov/speeches/speech.aspx?speechid=1453.

[6] Sec. Gates also described the purpose of export control as enabling the U.S. government "to concentrate on controlling those critical technologies and items – the "Crown Jewels" if you will – that are the basis for maintaining our military technology advantage, especially technologies and items that no foreign company or government can duplicate." *See id.*

scientific research telescopes are requiring increasingly larger lenses. If the U.S. government determines that it is necessary to control infrared lenses on the basis of size, Umicore proposes that large lenses (those exceeding 5 inches in diameter or length) that have no other special military properties should be regulated under the existing dual-use controls in ECCN 6A004, which already controls certain infrared optics components on the basis of their size.

In connection with removing infrared lenses entirely from ITAR control, the following parameters would be appropriate for the 600 series, to capture the limited set of lenses or lens assemblies that are unique to military applications:

- Lenses with resistivity less than 5 ohm centimeters at 20 degrees Celsius;
- Lenses coated for a military application, including for purposes relating to counter-counter measures against electromagnetic interference and other forms of electronic warfare;
- Lenses specially designed for use in missile applications, with dome shaped contouring;
- Lens assemblies that are space qualified;
- Lens assemblies with a focal length exceeding 100 mm, combined with a resolution exceeding XVGA, which factors together create a high performance long-distance lens; or
- Lens assemblies specially designed to function with cooled thermal imaging systems.

IV. Umicore's Proposed Alternate Control Thresholds

Below is a summary of the alternate controls proposed by Umicore for infrared lenses.

	Optics Blanks	**Infrared Lenses/Assemblies**
USML Cat. XII	None	None
ECCN 6A615	• Germanium blanks only, with resistivity below 5 ohm centimeters at 20°C. • No chalcogenide blanks.	• Lenses with resistivity less than 5 ohm centimeters at 20 degrees Celsius; • Lenses coated for a military application, including for purposes relating to counter-counter measures against electromagnetic interference and other forms of electronic warfare; • Lenses specially designed for use in missile applications, with dome shaped contouring; • Lens assemblies that are space qualified; • Lens assemblies with a focal length exceeding 100 mm, combined with a resolution exceeding XVGA, which factors

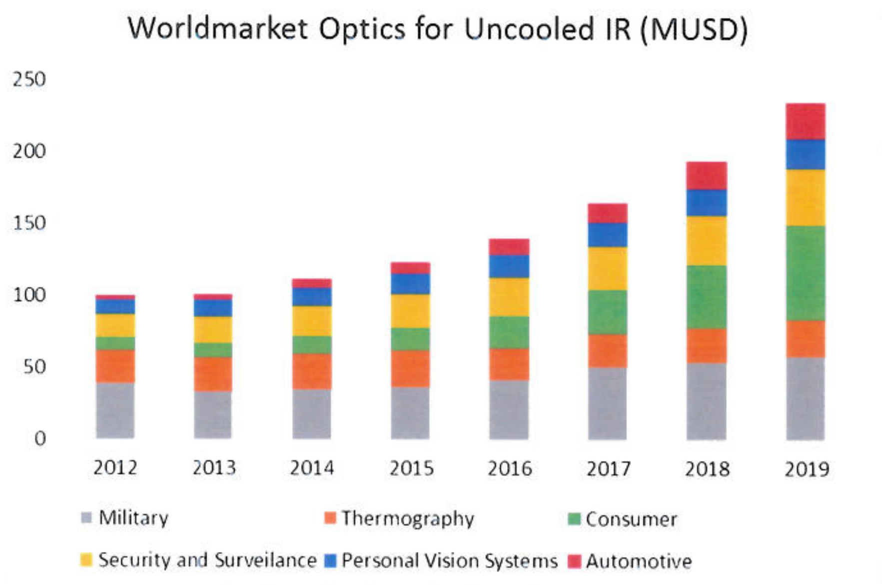
		together create a high performance long-distance lens; or • Lens assemblies specially designed to function with cooled thermal imaging systems.
ECCN 6A004	• Chalcogenide blanks exceeding 5 inches in diameter or length. • No size controls for germanium blanks.	• Finished infrared lenses made from any materials that exceed 5 inches in diameter or length.
EAR99	• Default for optics blanks, unless captured under positive controls in ECCNs 6A615 or 6A004. • Crystalline germanium in ingots, bars, or discs, which have not yet been processed into optics blanks. • Infrared windows comprised of any material, which have not been optically worked and have no curvature or optical power.	• Default for infrared lenses and lens assemblies not captured under ECCN 6A615 positive controls.

Umicore greatly appreciates this opportunity to provide comments on this proposed rulemaking. Should the Commerce Department require any further information, the undersigned may be contacted at: thomas.mckelvey@am.umicore.com or at (919)-874-2127.

Respectfully submitted,

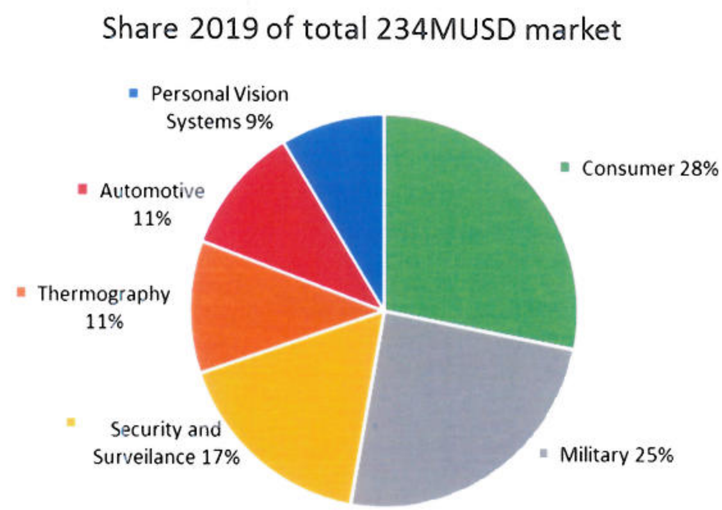
Thomas R. McKelvey
Umicore USA Inc.
Regional Trade Compliance Manager

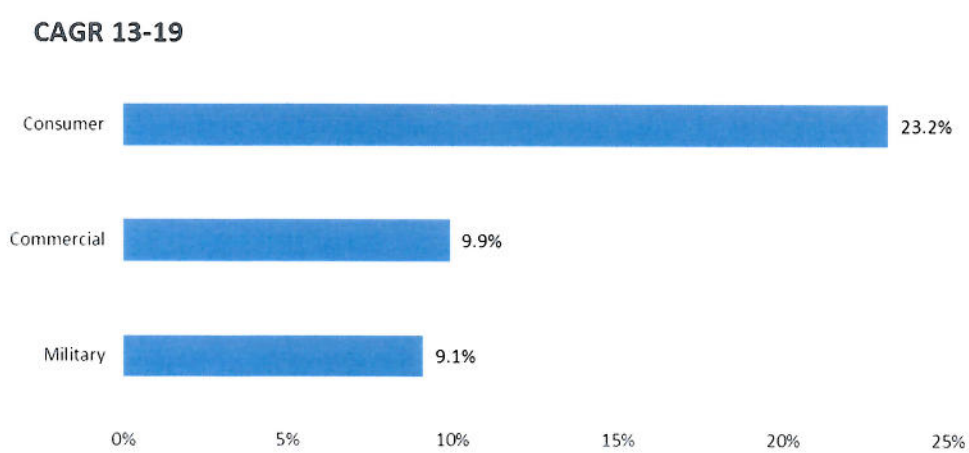
APPENDIX



MUSD = $ U.S. dollars, in millions

CAGR = cumulated annual growth rate





Examples of Foreign Optics Producers

Demonstrated technology and production capabilities equivalent to or exceeding U.S. industry.

Contents

Examples of Foreign Blanks Products

Photonics Sense – Germany
Germanium blanks up to 500mm (20") diameter
http://www.photonic-sense.com/images/PDF_DB/Germanium_DB_en_Kompromiss_140407.pdf

OJSC – Russia
Germanium blanks up to 200mm (8") diameter
http://www.made-in-zelenograd.com/companies/ojsc-germanium/#page4
and
http://www.ved.gov.ru/eng/companies/exporters/?action=companyinfo&id=34533

Examples of Foreign Window Products

Diameter > 5"

Wavelength – Singapore

Part No.	Material	Diameter (mm)	Thickness (mm)	Wavelength(um
WGE-142-6-BB	Ge	142.0	6.0	8-12
WGE-150-15-BB	Ge	150.0	15.0	8-12
WGE-152X120X6.54-BB	Ge	152*120	6.5	8-12
WGE-156-6-BB	Ge	156.0	6.0	8-12
WGE-160-6-BB	Ge	160.0	6.0	8-12
WGE-178-6-BB	Ge	178.0	6.0	8-12

http://www.wavelength-tech.com/IR-Optics/WindowIR.jsp

Examples of Foreign Lens Assembly Products

Focal Length Greater than 100mm

Shalom EO - Israel
IR Lenses for 640x480-25um LWIR uncooled FPA Detectors

No.	Module	Focal length (mm)	F #	FOV (H x V)	Focus Mechanism	Flange Back Dist (mm)	Mechanical Connector
9	2120F1.0	120	1.0	7.6°x5.7°	Motorized	20	M54x1
10	3123F0.8	123	0.8	7.4°x5.6°	Motorized	20	2.325" -12TPI
11	2150F1.0	150	1.0	6.1°x4.6°	Motorized	20	M54x1
12	3180F1.2	180	1.2	5.1°x3.8°	Motorized	14.8	Flange
13	2200F1.3	200	1.3	4.6°x3.4°	Motorized	20	2.325" -12TPI
14	3275F1.4	275	1.4	3.3°x2.5°	Motorized	20	2.325" -12TPI

http://www.shalomeo.com/product/thermal-imaging/ir-lenses-for-uncooled-thermal-imaging-cameras/lens-for-640x480-25um-fpa-19.html

Dual FOV and Zoom Lenses for 640x480-17um LWIR uncooled FPA Detectors

.	Module	Focal Length (mm)	F#	FOV (H x V)	Focus Mechanism	Flange BackDist (mm)	Mechanical Connector
1	DF-22.6F0.9-114.5F1.0 Double FOV	22.6	0.9	24°x18°	Motorized	32	flange
		115	1.0	4.8°x3.6°			
2	DF-44F1.0-132F1.1 Double FOV	44	1.0	12.5°x9.4°	Motorized	15	M45x1
		132	1.1	4.2°x3.1°			
3	DF-42/0.82-107/1.0 Double FOV	42	0.82	13°x9.8°	Motorized	30	flange
		107	1.0	5.1°x3.9°			
4	DF-51/1.1-153/1.2 Double FOV	51	1.1	10.8°x8.1°	Motorized	15	M45x1
		153	1.2	3.6°x2.7°			
5	DF-25/0.9-75/1.0 Double FOV	25	0.9	21.7°x16.4°	Motorized	19.67	2.325"- 12TPI
		75	1.0	7.3°x5.5°			
6	DF-50/0.9-150/1.0 Double FOV	50	0.9	11°x8.2°	Motorized	28	flange
		150	1.0	3.7°x2.7°			
7	DF-35/0.9-140/1.0 Double FOV	35	0.9	15.6°x11.7°	Motorized	13.5	flange
		140	1.0	3.9°x2.9°			
8	Zoom-25/0.95-75/0.95 countinuous	25~75	0.95	8.3°~24.6° x 6.2°~18.5°	Motorized	20	flange
9	Zoom-20/1.1-60/1.1 countinuous	20~60	1.1	10.4°~30.4° x 7.8°~23.1°	Motorized	20	M54x1
10	Zoom-53/0.8-105/0.94 countinuous	25~75	0.8 ~ 0.94	5.9°~11.7° x 4.4°~8.8°	Motorized	20	M54x1

http://www.shalomeo.com/product/thermal-imaging/ir-lenses-for-uncooled-thermal-imaging-cameras/double-fov-and-zoom-ir-lenses-2.html

Sunny Ningbo – China

F(Mm)	F#	Sensor	T 8-12	Fov(°)	Focus
130	1.2	640*480 17μm	>84%	4.8(H)×3.6(V)	Motorized
150	1	640*480 17μm	>87%	4.1(H)×3.1(V)	Motorized
150	1.2	384*288 25μm	>84%	3.7(H)×2.8(V)	Motorized
f37.5-f150	1.2	640*480 17μm	>86%	f37.5=16.9(H)×12.6(V), f150=4.2(H)×3.1(V)	Motorized Continuous Zoom
f60- f180	1.4	640*480 17μm	>86%	f60=10.4(H)×7.8(V), f180=3.5(H)×2.6(V)	Motorized Continuous Zoom

http://www.sunnyoptical.com/en/009002008/p324.html

Wavelength – Singapore

Part No.	Focal Length(mm)	F/#	Detector	Wavelength	Focus Type
Infra-LW1501.0-17	150	1.0	640x480, 17um	8um-14um	Manual Focus
Infra-LW1501.2-17V2	150	1.2	640x480, 17um	8um-14um	Manual Focus
Infra-LW1501.4-17	150	1.4	640x480, 17µm	8um-14um	Manual Focus
Infra-LW1502.0-17	150	2.0	640x480, 17µm	8um-14um	Manual Focus

http://www.wavelength-tech.com/IR-Optics/LWIRInfraLens.jsp

Resolve Optics – United Kingdom

Focal Length	F/Number	Focus Type	Spectral Range
120	1.2	Fixed	8-14um

http://www.resolveoptics.com/ir-lens-320-000.html

Tamron – Japan

Detector Size 17µm pixel pitch VGA (640×480)	Standard M34 Screw		Model No.	Focal Length	F number	Max object distance (m)	Remarks
			▸ LVZ3X3516N/A	35-105mm	F/1.6	3,083	

http://www.tamron.biz/en/data/thermal/index.html

12 micron pixels or smaller

Ophir - Israel

Focal Length	F/Number	Focus Type	Spectral Range	Part Number
18mm	1.0	Fixed	8-12um	65058
25mm	1.0	Manual	8-12um	65136
35mm	1.0	Manual	8-12um	65141
50mm	1.0	Manual	8-12um	65163
75mm	1.0	Manual	8-12um	65022
100mm	1.0	Manual	8-12um	65040
150mm	1.0	Motorized	8-12um	65043

http://www.ophiropt.com/infrared-optics/catalog-infrared-lenses/lenses-for-uncooled-cameras

Additional Chinese Optics Producer Information

Finished Optics

Yunnan KIRO, China
http://www.kiro.cn/English/ProductList6939.html?PTid=114

Beijing LensTech, China
http://www.lenstec.net/en/www/product.asp

Nanjing Wavelength Opto-Electronics
http://wavelength-tech.en.alibaba.com/productgrouplist-218403840/IR_Optics.html

Germanium
Yunnan KIRO, China
http://www.kiro.cn/English/ProductView064e.html?Pid=27

China Germanium Industry News Coverage
http://www.prnewswire.com/news-releases/global-and-china-germanium-industry-report-2013-2016-300045533.html

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July 6, 2015

Office of Defense Trade Controls Policy
U.S. Department of State
Washington, D.C.

By email to DDTCPublicComments@state.gov, subject "ITAR Amendment—Category XII"

RE: RIN 1400-AD32

Dear Sirs/Madams:

The University of Arizona appreciates the opportunity to comment in response to the Department of State RIN 1400-AD32, *Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII.*

We appreciate the efforts of the Departments of State, Defense, and Commerce to clarify the export control regulations. RIN 1400-AD32, and the accompanying RIN 0694–AF75 revising the EAR, represent progress toward positive USML and CCL descriptions of controlled items. However, these proposed rules represent an increase in controls that would adversely affect the conduct of academic research activities in a wide range of fields including astronomy, space science, and photonics. There should be a clear delineation between items that that have military and non-military uses.

The University of Arizona is specifically interested in contributing to the export reform effort in order to ensure that the resulting regulations do not have an adverse impact on academic pursuits, and offer the following comments.

Request for note to be added to Category XII

We would recommend that Category XII includes a note saying that:
"Category XII does not apply to items that are specifically made for non-military end uses, such as astronomy, including stationary ground-based systems and telescope instruments, meteorology, other research or commercial end uses".

Comments on ITAR XII (b)(2)

There are commercial products (e.g., laser trackers) which meet this definition and cannot be converted to defense use. We recommend that the technical parameters be changed so as not to restrict commercially available products for metrology and land survey applications.

Comments on ITAR XII (b)(3)(i)(ii)
There are commercially available products (e.g., FLIR, a commercial company) that would now be ITAR-controlled under this definition. We recommend that the technical parameters be changed so as not to restrict commercially available products for metrology and land survey applications.

Comments on ITAR XII (b)(6)-(8)
XII(b)(6)-(8) – LiDAR systems can be used for meteorological purposes. It is possible that meteorological systems can be built to the specifications described in paragraphs (7)-(8).

Request for note to be added to Category XII (b) (6)-(8)
A note should be added that paragraphs (6)-(8) do not control LiDARs or other laser range-gated systems or equipment built for meteorological purposes or already commercially available.

Comments on ITAR (b)(11) and (b)(12)
Increasing the power from 1W to 2W is helpful.

Comments on ITAR (b)(13)
A power density of xxW/cm2 is stated, and power density depends on how the laser is focused using lenses external to the laser itself. This will be confusing because it is mostly an issue of how the user will use the laser, and we typically assume the laser is focusable.

Request for Wording Changes to ITAR XII (b)(13)

- We suggest the power density be changed to power (in terms of Watts) and also point to the focusability of the laser.
- Item (b)(13)(iv) should be deleted because companies such as IPG Photonics already sell commercial lasers at that wavelength with 100 times more power, in the several kW range.

Comments on ITAR XII (b)(14)
This sub paragraph is an overly broad statement of control that implies the funding source (Department of Defense) of lasers or laser systems will dictate whether or not the systems should be controlled as a munition. Per Note 1 to paragraph (b)(14), if a contract fails to include language that the system or equipment being developed is for both civil and military applications, then the system or equipment would therefore be ITAR-controlled.

Much initial work on lasers and laser systems is based on public domain information, conducted by universities, and may be sponsored under Department of Defense 6.1 (basic research) or 6.2 (applied research) funding, which in most cases would be considered fundamental research under the ITAR.

Request for Wording Changes to ITAR XII (b)(14)

The proposed wording of this sub paragraph if not clarified will negatively impact research conducted at universities. Lasers not meeting the requirements for a military end use should not be controlled under ITAR, even if their development was funded by the Department of Defense.

Under the proposed definition of "development" (80FR 31525), it states "all stages prior to serial production, such as: design....", which could be thought to include any basic or applied research which is used in the design. This is clearly counter to the definition of fundamental research. The definition should include a statement that development does not include that work which would be considered fundamental research.

Comments on ITAR XII (c)

XII(c)(2)-(12) – Infrared focal plane arrays (IRFPA) may be used in astronomy in the development/production of land-based telescopes. These telescopes have a scientific purpose and do not have a military end use. Astrophysical investigations have expanded, along with technology, to encompass nearly all wavelengths. The infrared bands, which appear to be the subject of the new regulations, are especially important with their ability to see things otherwise blocked in the optical by gas and dust in the interstellar medium. These proposed regulations will affect infrared and sub-millimeter instrumentation.

Some techniques and hardware used in infrared instruments will be proposed for use at other wavelengths, including the X-ray band. The same bolometers used in the infrared have been adapted to be used in the X-ray band, for instance. State of the art infrared detectors for instruments that may be proposed/flown on scientific satellites and may be and are used in ground-based telescopes outside of the U.S. may be impacted by the proposed export regulations. MilliKelvin bolometers are used in the X-ray wavelength bands, as they are used in the infrared and would also be affected by the proposed changes. Many of the best ground based astronomical sites are not in the United States, but in Chile, the Canary Islands, South Africa and other foreign destinations. Additionally there are multi-national teams participating in this research with these instruments and ITAR jurisdiction of these items could exclude participation of certain nationals.

Comments on ITAR XII Note 1 to paragraph (c)

The intent of this Note is unclear and should be clarified as to its applicability.

Comments on ITAR XII Note 2 to paragraph (c)(2): 12 (iii)

Some of these requirements are causing undo competitive advantage for foreign companies. For example, the proposed requirements will give Sofradir, a French company that produces bolometers and photon detectors, an advantage over U.S. companies.

Request for Defined Terms ITAR XII(c)(2), (c)(4) and (c)(12)
We would recommend the following terms be defined:

- XII(c)(2) – "Integrated".
- XII(c)(4) – "Permanent encapsulated sensor assembly".
- XII(c)(12) – "Infrared imaging camera core".

Comments on ITAR XII (c)(7)
Current commercial applications of charged multiplication FPAs are now at 1,000 elements, but it is believed the commercial world will surpass 1,600 elements in the near future. Currently, there are leading foreign suppliers, such as Andor, with headquarters in the UK and locations in China, Japan and the U.S. of electron multiplying charge coupled devices for scientific, non-military-related research. Current applications for these cameras are for smaller devices but larger devices will soon be available from such foreign suppliers (e.g. greater than 1,600 elements in any dimension and having a maximum radiant sensitivity; exceeding 50mA/W for any wavelength exceeding 760 nm but not exceeding 900nm and avalanche detector elements).

Comments on ITAR XII(c)(9)
Even though the IRFPA (used in a land-based telescope) may have been developed for spaceflight or military use, we consider XII(c)(9) as overly broad when applied to commercial dewars, cooling systems and electronics that were not specifically designed to be used with controlled IRFPAs. Nor do we see a value in controlling the integrated dewar cooler assemblies which are custom-made for astronomical purposes. Under the proposed XII(c)(9), dewars, cooling systems, electronics and optics that were designed for commercial purposes would be controlled under the ITAR solely because of their use with a controlled IRFPA. Integrated IRFPA dewar cooler assemblies (IDCAs), with or without IRFPAs, can be put together easily by anyone who purchases a cooler from commercial suppliers such as Air Liquide, and a commercially available infrared detector array can be currently purchased from a U.S. company.

Examples of commercial cryocoolers using fully encapsulated detector array systems could include Pulse-tube cryocoolers, Gifford-McMahon cryocoolers, sorption refrigerators, adiabatic demagnetization refrigerators, and dilution refrigerators (not an exhaustive list), all of which are used for cooling astronomical focal planes and which are well-described in literature in the public domain. Examples of ECCN designations for commercial equivalent products captured by the revised ITAR XII include:

- Cryomech, Inc. - Gifford-McMahon Cryorefrigerators are EAR99 for part numbers: AL10, AL25, AL60, AL63, AL125, AL200, AL230, AL300, AL325, AL330, AL600.
- SHI Crygenics - Pulse Tube Cryocooler Series are EAR99 for part numbers: RP-062B 4K Pulse and RP-082B2 Pulse.

These commercially available devices could be purchased and used for other purposes without being subject to the ITAR, but once the products are associated with a controlled IRFPA, the devices would need to be controlled. This leads to a confusing and poorly manageable situation for a scientific or research organization.

Because these components would be subject to ITAR restrictions, details of their design or integration into the IRFPA system could not be discussed in scientific publications. However, because these are commercial products, it is very possible that details of their design and use are already in the public domain.

Request for Defined Terms ITAR XII(c)(9)
We request a better definition of what is included in an integrated IRFPA dewar cooler assembly. For example, are the following items to be included?

1. Optics within the dewar.
2. Cooling system components installed outside of the dewar, in some instances mounted at a distance from the dewar or part of a telescope facility and not directly part of the instrument.
3. Electronic control systems for the cooling system, which again may be mounted away from the dewar.
4. Systems used to control heating of the dewar (separate from the cooling system).
5. Optics mounted outside of the dewar that interface with the optics within the dewar.

Request for Wording Changes to ITAR XII (c)(9)
We recommend that integrated IRFPA dewar cooler assemblies (XII(c)(9)) be removed from ITAR control or reworded to remove ITAR controls on commercial or custom components made for non-military, scientific purposes.

Comments on ITAR XII (c)(17)
While certain telescopes do not meet this description the components could be rearranged to meet or exceed these technical parameters. Six meter telescopes may likely exceed these technical parameters. We recommend that the technical parameters be increased. We recommend that the mirror size be changed to be greater than 8.4m to recognize the existence and operation of presently operating observatories such as Keck and the Large Binocular Telescope.

Comments on ITAR XII(e)
This section has similar concerns to XII(c)(9) and is overly broad in its controls. It does not specifically state what technologies need to be controlled or specify the end uses of that technology.

<u>XII(e)(7)(i)</u> – Stirling cryocoolers are based upon technology that was conceived in the 1800s, have been produced since the mid-1900s and are well-described in the public domain. Protecting this technology would not appear to improve national security.

Request for Wording Changes to ITAR XII (e)(7)(i)
Stirling cryocoolers should be exempted even though they may meet the specifications as described in this section.

Comments on ITAR XII(e)(7)(iv)
Dewars that are specially designed for IRFPAs for non-military purposes (astronomy) impart little, if any, information regarding the technology of the IRFPA that is not already described in the literature (for the particular IRFPA being used). Controlling the dewar because of its use with a controlled IRFPA can provide similar concerns as described in Comments on ITAR XII(e)(9) below.

Comments on ITAR XII(e)(9)
This section should consider the application of the parts and components. A land-based astronomical telescope that contains an IRFPA would likely include numerous optical elements including lenses, beam splitters, mirrors, filters, gratings and etalons, many of which could be treated or coated in specific manners.

It can be difficult to find a company to make custom optical elements for such a scientific device when considering process capabilities (of the company to make a specific element), quality considerations, cost and delivery schedules. In some instances, the best candidate may be a foreign vendor. An export license would be required to export the design specification as technical data for the manufacture of these components and would increase Agency and project workload, solely because these elements are to be used with an IRFPA.

Also, domestic vendors that produce such optical elements may need to review their staffing to determine whether a license is required for any foreign persons working within their facility. Alternatively, they may decide that they will not supply optics for equipment that contains ITAR components due to the overhead costs in supporting that activity. Any of these scenarios could compromise a research organization's ability to procure or create high quality optical elements. This issue also would increase the regulatory burden on the research project, vendor and Agency with no likely national security impact.

XII(e)(9) – This paragraph is overly broad in that it can include optical elements that are not enclosed or attached to the IRFPA dewar cooler assembly. This could be read to include all optical elements within the beam path of a scientific instrument.

In some cases foreign graduate students may be developing these custom optical elements as part of their studies and are actively participating in the manufacture of these items in machine shops at universities all under the auspices of fundamental research.

XII(e)(10) – The signal or image processing electronics may require custom electronics and software to produce a scientifically usable image when used with an IRFPA in an astronomical telescope. The application of the IRFPA should be considered when reviewing what is controlled. Uses that are not considered military should not be controlled under the ITAR, particularly for parts and components used in association with a controlled IRFPA.

If we look collectively at sections XII(c)(2)-(9), XII(e)(7) and XII(e)(10) and consider their application to a land-based astronomical telescope using a controlled IRFPA, the entire functional portion of the telescope would be controlled regardless of whether the assemblies, parts and components were custom or commercial items, merely because they are used with an IRFPA. The list of items that would need to be controlled include mirrors, lenses, beam splitters, coatings/treatments on optics, filters, gratings, etalons, dewars, cooling systems for dewars, controllers for the cooling systems, imaging electronics, image processing hardware and software, and any electronics interfacing with the IRFPA.

In a telescope, this may require the control of tens to hundreds of parts, which would be a severe hardship on a research institution or university. Vendor control would be extremely hard to manage and may result in some vendors not wanting to manufacture parts (for such ITAR controlled projects), thereby limiting the research institution's ability to source quality parts and components.

We consider the control of all of these components because of their association with an IRFPA to be a severe overreach that provides no particular additional security regarding the technology the government wishes to control, namely the IRFPA.

Since the entire imaging chain of the telescope would be controlled, publication of the design of the telescope would not be possible, thereby preventing researchers from advancing the design knowledge in their field (it would be a defacto publication restriction). Secondly, it may prevent universities or research institutions from taking on such a project due to the potentially extreme regulatory burdens of the project. In many instances, research instrumentation is developed by consortiums of domestic and foreign collaborators. The sort of regulatory controls described in the proposed regulations could lead to a substantial increase in licensing due to foreign collaborations.

This overreach on systems containing IRFPAs and associated parts and components is similar to Category XV for space technology prior to export control reform. If entire space systems, parts and components were moved from the USML to the CCL, why is the U.S. government putting commercial and research items by association with IRFPAs under munitions controls?

Request for definition on ITAR XII(e)(13)
Resonator needs to be defined. It is unclear if this is for a resonator for gain.

Request for Wording Changes to ITAR XII (c), (e) and (f)
An exemption to sections XII(c) and XII(e) should be made for assemblies, parts and components that are used in conjunction with an IRFPA for land-based astronomical and other non-military uses.

XII(f) – Technical data associated with assemblies, parts and components used in conjunction with a IRFPA for land-based astronomical telescopes and other non-military uses should be exempted from these requirements as described in section XII(c) and XII(e) above.

The University of Arizona appreciates the opportunity to provide the Department of State with the above comments on ITAR Amendment—Category XII to help the government understand how the technologies we are developing and using are being impacted by the proposed changes. The research enterprise in the United States is critical to the economic advancement of our country and having export regulations that are not overly broad ensure that innovation is not stifled in performing fundamental research.

Sincerely,

Mary Kay Ellis

Mary Kay Ellis
Director, University Export Control Program
University of Arizona
ellisk@email.arizona.edu

Memorandum

From: US Industry
U.S.A.

To: US Department of State
Directorate of Defense Trade Controls
2401 E Street NW, SA-1, Room H1200
Washington, DC 20522-0112

Re: Industry feedback report for the Category XII revised regulations

Date: 7/1/2015

The following provides clear guidance and feedback from US industry regarding the recommended changes to the Category XII regulations of the Munitions list. This feedback is specifically focused on the regulation changes associated with clause:

"(a)(4). Laser spot trackers or laser spot detection, location or imaging systems or equipment, with an operational wavelength shorter than 400 nm or longer than 710 nm, and a detection range greater than 300 m;"

And in part this clause as well:
" (c)(2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor"

Comment:

Clause (a)(4) is incredibly broad and impacts entire industries that were established decades ago that are intimately integrated into society today. To make the blanket statement that imaging a laser with a wavelength greater than 710nm (the 300m range criteria can be ignored since it doesn't specify a laser power nor an integration time) is ITAR restricted fundamentally transforms the consumer, commercial and industrial landscape. As much as it may be desired, photons are not distinguishable. A 850 or 940nm laser photon is no different than a 850 or 940nm LED photon or a 850 or 940nm photon from the sun. A camera designed to see 850/940nm LED light will also by definition see 850/940nm laser spots. This can't be prevented.

Since the CCL (Commerce Control List), for decades, has clearly defined the 400-1200nm range (historically based on silicon imaging sensor technology) as a commercial technology, this has provided clear and unambiguous guidance for commercial technology companies to innovate products within this wavelength range. Specifically, the CCL specified that imaging and detecting sensors with peak response less than 900nm are definitively non-controlled and furthermore defined sensors with peak response greater than 900 but less than 1200nm as non-controlled provided that the response time was slower than 95 nanoseconds. Given this, it is now impossible to turn around and prevent them from "seeing" lasers greater than 710nm. As written this clause is a very significant change that drastically impacts many commercial industries that have evolved over the past 30 years based on clear guidance in the CCL.

Insufficient scientific/technical detail

The clause (c)(4) is written with insufficient technical specification to accurately assess if a given technology qualifies for the clause. The clause calls out a limitation based on 300m detection range however, it fails to provide a framerate (integration time) of the sensor nor the power of the laser. Without these other parameters it is impossible to determine whether a given technology product qualifies. If a sensor has 0.1% quantum efficiency and 1 sec of integration time produces the same signal as a sensor with 10% quantum efficiency and 10 msec of integration time assuming the same brightness scene. As such, if you stare long enough you can detect at 300m range.

Here is an assessment of various commercial products that are impacted:

3D gaming consoles:

Microsoft X-box Kinect gaming console and Microsoft HoloLens virtual reality headset use 850 and 940 laser spots to perform 3D imaging. The system works by projecting laser spots onto the scene and then capturing near infrared images of those laser spots to recreate a 3-dimensional view of the world. The X-box Kinect has sold in excess of 24 millions of units worldwide. Microsoft has "opened" the software programming interface to allow access for 3rd parties to develop applications (Apps) for the gaming console. This open architecture gives everyone access to the raw imaging data. As such, it is now possible to turn off the laser pattern and use the camera to see other lasers. Since the Kinect is specifically designed to image 850 and 940 laser spots, it satisfies the clause and therefore will be ITAR restricted.

Day/Night Security Cameras

The entire class of Day/Night security cameras would be subject to ITAR restriction should this clause be adopted. Day/Night security cameras (representing 40M world wide commercial units and roughly $10B sales annually from companies including: Honeywell, Tyco, DropCam/Nest/Google, Axis, Bosch, HIKvision, Samsung, etc.) utilize CMOS or CCD imaging arrays that have sensitivity out to 1200nm. At low light these cameras mechanically remove the near infrared cut-off filter and then use near infrared lasers or LEDs at wavelengths from 780, 850, 940, and 1060nm to see. You can in fact walk into any Home Depot today and buy a SPT Outdoor Laser Illuminator at 850 and 940nm wavelengths for extended range security cameras. As such, these devices are "laser spot detection, location or imaging systems or equipment with an operational wavelength longer than 710nm." Since lens focal length is customizable on virtually all security cameras, selecting a higher magnification lens will enable the imaging of laser spots at ranges greater than 300m quite easily.

The clause also specifies a detection range without defining the intensity of a laser spot. With a bright enough laser, this clause will be satisfied with a smart phone camera (Apple iphone, Motorola X, Samsung Galaxy, etc.). Today's commercially available, commercially developed smart phone cameras have an IR cut off filter that starts its cutoff at 780nm. As such, any and all lasers in the 710-780nm will be visible to the smart phone camera. As such, all smart phones will become ITAR restricted as well. Furthermore, image sensor companies including Aptina (now ON Semiconductor) and Omnivision have more recently adopted color filter patterns that are comprised of red, green, blue, and white, or red, green, blue, IR that are specifically designed to operate without an IR cut off filter. These newer sensors are specifically designed for cell phone camera modules and have the ability to image out to 1100nm. These sensors can and will image laser spots in the 710-1100nm spectral regime.

The clause also specifies a limitation of "greater than 300m range". To be technically accurate, this really provides no limitation what so ever. The limitation does not define the laser power nor the integration time of the sensor/camera. Without these other critical factors, if you stare long enough or use a bright enough laser, just about any imaging devices will see the laser spot. Since it is commonplace for nighttime security cameras to dramatically increase integration time to improve low light detection, it will be straightforward to satisfy this "limitation".

Medical Endoscopes:
These imaging systems from companies including Johnson and Johnson, Smith and Nephew, Boston Scientific, Olympus, Stryker, Medtronic, etc. are specifically designed to image laser illumination in the range from 700-1200nm as this is a "transparent" window in human tissue. The endoscope delivers a laser pulse to the body, and the imaging system captures images of the tissue as well as light generated from "taggants" (fluorescent probes). Endoscopes have the ability to focus at infinity and therefore can be used to image scenes far away rather than close in simply by directing the optics in a given direction.

Amazon Fire Phone:
The Fire Phone has 4 near infrared imaging cameras to image both 850 and 940 LEDs and lasers (also on the phone) in order to do 3D imaging.

3D imaging technology
The entire class of 3D imaging technology (structured light based or time of flight) including the Intel RealSense camera, LeapMotion, Google Tango, and many more. These 3D imaging products perform LIDAR (also subject to ITAR restriction in another clause) but will be able to see a near infrared laser greater than 710 nm.

Near infrared industrial cameras.
There is a large established industry for performing manufacturing monitoring that use cameras in the near infrared from 800-1200nm. These include wafer inspection, food inspection, solar cell inspection, plastics inspection, and many many more. All of these cameras would become ITAR restricted. Companies that sell these cameras include: Cognex, IDS, Allied Vision Systems, Illunis, Baumer, Teledyne-Dalsa, Imprex, etc.

Conclusion
We hope we have made clear the severity of the clause, the scientific inconsistencies there of, and its dramatic negative impact on the competitiveness of US commercial industry. Nearly all of the above disclosed technology products were in fact innovated here in the US and up until now have been clearly considered commercial and non-controlled. To now no longer allow US

companies to benefit from their innovations and instead hamper them with burdensome regulations is a travesty. There is clear evidence that export restriction fundamentally hamper US companies while providing a competitive leg up for our European and Asian competitors. The ability to service world markets provides the economies of scale to drive manufacturing volume up and drive costs down. Without these economies of scale it would be impossible to get a smart phone for $100. If we prevent US companies from addressing world markets (by restricting the above described technologies to US only) we will drastically reduce manufacturing volumes and therefore cost leverage for US companies only. The result will be that US companies products will be more expensive than imported products and US companies will lose customers.

United Technologies Corporation
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United Technologies

Submitted Via Email

July 6, 2015

Mr. C. Edward Peartree
Director, Office of Defense Trade Controls Policy
PM/DDTC, SA-1, 12th Floor
Bureau of Political Military Affairs
U.S. Department of State
Washington, D.C. 20522-0112

Attn: Regulatory Change, USML Category XII

Re: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII (80 Fed. Reg. 25821, May 5, 2015)

Dear Mr. Peartree:

United Technologies Corporation ("UTC")[1] appreciates the opportunity to submit these comments on the implementation of Export Control Reform ("ECR") with respect to fire control, range finder, optical and guidance and control equipment. UTC strongly supports the Administration's goals of creating a positive, transparent, and predictable structure within the categories of the U.S. Munitions List ("USML"), and continually aligning this structure and associated export control policies with changing technological and market conditions.

The proposed changes to USML Category XII capture items currently in production that are in normal commercial use and available worldwide from foreign manufacturers (e.g., one-dimensional linear arrays and cameras with more than 640 detector elements, two dimensional camera cores, EO-only and EO/IR gimbals, wafers, and infrared lenses) by using non-military performance parameters for control, including infrared wavelength, resolution, and stabilization. The proposed control on the USML of products and their parts, components, and accessories that are in current commercial use will increase costs on manufacturers and their OEM customers. This will reduce the global competitiveness of U.S. industry.

UTC conducted a thorough review of the proposed amendment to USML Category XII and the corresponding changes in the Commerce Department's proposed rule to implement new "600 series" controls, and focused its comments on four main themes:

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[1] UTC is a global, diversified corporation based in Hartford, Connecticut, supplying high technology products and services to the aerospace and building systems industries. UTC's companies are industry leaders, among them Pratt & Whitney, Sikorsky, UTC Aerospace Systems, UTC Building & Industrial Systems, and United Technologies Research Center.

- Goals of ECR;
- Identifying the proposed performance 'redlines' that capture items in normal commercial use;
- Foreign availability; and
- Proposing new control language that better distinguishes military from commercial items.

As described in more detail below, UTC believes the proposed revision of USML Category XII should be fundamentally restructured to fully support the goals of ECR and limit the negative impact to U.S. industry.

I. USML Category XII(a) – Fire Control, Weapons Sights, Aiming, and Imaging Systems and Equipment

A. Add Note to Category XII(a)(1)

UTC respectfully suggests that DDTC clarify Category XII(a)(1), which controls fire control systems or equipment, and specially designed parts and components. Fire control computers are currently enumerated in Category VIII(h)(16), which includes fire control computers, stores management systems, armaments control processors, aircraft weapon interface units and computers. Category VIII(h)(16) is not considered Significant Military Equipment ("SME") and does not control specially designed parts and components like the proposed Category XII(a)(1). Specially designed parts and components of the fire control computer are currently controlled as ECCN 9A610.x. It is not clear if DDTC's intent is to move fire control computers and specially designed parts and components from the recently revised Category VIII to XII(a)(1) and control these items as SME.

UTC recommends DDTC clarify this position and not move fire control computers for aircraft controlled by Category VIII(h)(16) to the revised Category XII(a)(1). UTC requests DDTC include a note to Category XII(a)(1) stating that this does not include fire control computers for aircraft and specially designed parts and components therefore that are controlled in Category VIII(h)(16) and ECCN 9A610.x.

B. Amend and Remove Detection Range Parameter for Category XII(a)(4)

UTC recognizes the requirement to control military laser spot trackers or laser spot detection, location or imaging systems as defense articles that provide the United States a critical military and intelligence advantage. The proposed language does not clearly define the term 'laser spot' and may inadvertently capture commercial imaging systems that are capable of detecting lasers with an operational wavelength longer than 710 nm. For instance, high-volume Silicon-based color image sensors have response past 710 nm, including cell phone cameras. The spectral response curve of a 5 megapixel sensor used for commercial applications is shown in Figure 1 and demonstrates response at typical laser designator wavelengths.[2]

[2] ON Semiconductor MT9P031 Datasheet, Rev. H, available at: https://www.aptina.com/products/image_sensors/mt9p031i12stc/

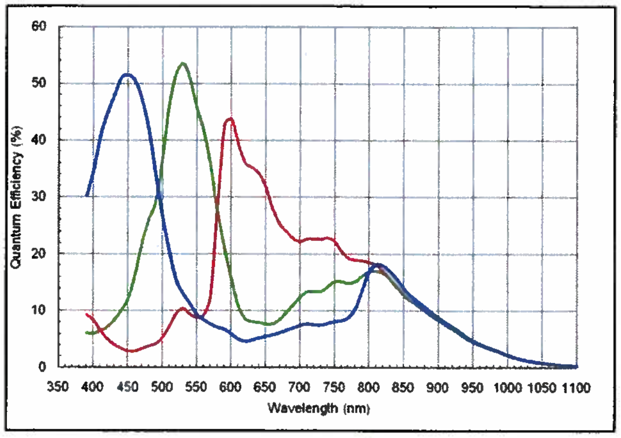

Figure 1- 5 Megapixel Sensor for Video and Web Cameras

Laser beam profilers used in telecommunication networks are an example of commercial imaging systems for lasers that may be captured by the draft language. Beam characteristics including shape, stability, uniformity, and wavefront direction, can help detect where a potential misalignment or optical loss might occur. Indium Gallium Arsenide ("InGaAs") focal plane arrays (FPAs) and Short Wave Infrared ("SWIR") cameras are integral components for spatial analysis of lasers and optics in the 900 nm to 1700 nm spectral band and are frequently integrated into laser and optical fiber analysis instrumentation. This spectral band is widely used within commercial telecommunications equipment for real-time network monitoring control of optical channel switchers and development of associated equipment. The current language may capture these imaging systems without additional clarification.

The detection range control parameter of 300 m may not provide the Department with a useful control parameter. Detection range is largely dependent on optics and other factors and is not necessarily an accurate figure of merit for the performance of the laser trackers or spot detection systems. As an example, a military laser spot tracker or detection system that meets the wavelength control parameter could be developed or modified with an optic that only detects up to 275 m in certain conditions. This modified system may not be captured by the proposed language in Category XII(a)(4).

UTC recommends DDTC amend Category XII(a)(4) to ensure the entry only captures laser spot trackers or laser spot detection, location or imaging systems specially designed to detect military laser target designators or coded target markers controlled in the revised Category XII(b)(1). DDTC should consider removing the detection range control parameter of 300 m and adding a note to XII(a)(4) that defines the term 'laser spot' specific to the military application of concern.

C. Include Specific Military Performance Parameters for Category XII(a)(8)

Remote wind-sensing systems or equipment specially designed for ballistic-correct aiming are not inherently military-only systems. Category XII(a)(8) may capture commercially available anemometer/wind direction sensors with wireless capability used for ballistic-correct aiming.[3] UTC recommends DDTC consider including specific, positive military performance parameters, including accuracy, resolution, update rate, and latency to distinguish between commercial and military systems that warrant ITAR-control and are not in normal commercial use. Adding control parameters also may alleviate concern that this could inadvertently capture other anemometer/wind direction sensors with wireless capability.[4]

II. USML Category XII(b) – Lasers and Laser Systems and Equipment

A. Clarify XII(b)(2) Language

The current XII(b)(2) entry controls aiming or target illumination systems **or** equipment having a laser output wavelength exceeding 710 nm; this may lead classifiers to believe that *any* equipment having a laser output wavelength exceeding 710 nm is controlled and inadvertently capture non-military items. This includes high-end permanent hair removal machines that use diode lasers with an output wavelength exceeding 800 nm and are available worldwide. An example of a commercial system with a laser output wavelength exceeding 710 nm is the IPL Beauty Machine Laser available from the Beijing Sincoheren Science & Technology Development Co., Ltd. in China.[5] UTC recommends DDTC revise the control to "aiming or target illumination systems **and** equipment" to clarify that this control is for aiming or target illumination equipment, not all equipment with laser output wavelength exceeding 710 nm.

B. Revise XII(b)(3) Laser Rangefinders

Laser range finders captured by this proposed control are included with EO/IR systems on commercial helicopter platforms being used for civil Search and Rescue ("SAR"). The civil SAR role is discussed in Section III(G). These range finders are captured because their wavelength exceeds 1,000 nm. For example, the wavelength of one such eye-safe range finder is 1.54μm (or 1,539.9 nm). UTC requests DDTC revise this entry due to the non-military use of laser rangefinders captured by this paragraph and include a carve out for commercial applications, including civil SAR.

C. XII(b)(6)-(8) LIDAR/LADAR

As discussed below, light detection and ranging (LIDAR) and laser detection and ranging (LADAR) systems and equipment are expected to have future commercial helicopter applications. Therefore, certain changes to the proposed Category XII revisions are requested.

1. Future Commercial Helicopter Applications

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[3] This is not a UTC product but came up in a search for ballistic-correct aiming systems: http://kestrelmeters.com/products/kestrel-4500-horus-atrag-ballistics-1

[4] Marine anemometer/wind direction sensors: http://www.raymarine.com/view/?id=1101

[5] Please see the following site for a commercial machine that may be controlled by the new language: http://www.ipl-lasermachines.com/sale-353864-permanent-high-performance-808nm-diode-laser-hair-removal-machine-for-all-hair-color.html

For low-flying aircraft, such as helicopters, obstacle avoidance is critical to operational safety and success. This capability is important when visibility is reduced, but also is applicable when visibility is good because certain obstacles (e.g., power lines) are difficult to detect from the air. Also, flying and landing in degraded visual conditions when there is blinding dust, smoke, sand, rain or snow presents a particular challenge to maintaining situational awareness. Obstacle avoidance is important for piloted, autonomous and optionally-piloted helicopters.

Regarding optionally-piloted helicopters, Sikorsky has identified a commercial market demand for full-size optionally-piloted helicopters to transport cargo to offshore oil platforms. This role could be operational within the next five years. Other possible non-military roles include providing humanitarian aid in natural disasters, casualty evacuations, and firefighting.

LIDAR is expected to have an increasingly important role for obstacle detection and avoidance as well as situational awareness. As these areas are important to both military and non-military applications, LIDAR systems and equipment that do not provide a unique military capability should not be included on the USML.

2. Proposed Revisions and Comment

Although Category XII(b)(6) invokes the definition of "specially designed," this paragraph is a system- and equipment-level control. Therefore, the "specially designed" (b)(3) release will not be available for systems used on commercial platforms. The note to Category XII(b)(6) provides a carve out for LIDAR used for civil automotive applications having a range limited to 200 m or less. It is requested that this carve out be expanded to include civil helicopters. To accommodate optionally-piloted full-size helicopters, such as the commercial Sikorsky model S-76 ® and S-92 ® helicopters,[6] the range threshold should be extended to 1,500 m. There is a need to perceive the environment from a longer distance due to the speed of these aircraft. Regarding Category XII(b)(7), Sikorsky is not presently using synthetic aperture LIDAR systems in commercial applications, although there is the potential to do so.

Additionally, UTC believes Category XII(b)(8)(ii) may capture civil aircraft systems or equipment that have a laser output exceeding 1,000 nm and a detection range exceeding 500 meters for an obstacle with a diameter or width less than or equal to 10 mm. The paragraph references "wire, power line" as examples of such obstacles. There is no "specially designed" (b)(3) release opportunity. UTC requests that DDTC include a carve out for (b)(8)(ii) for civil helicopter applications and extend the distance threshold to 1,500 m.

[6] S-92 and S-76 are registered trademarks of Sikorsky Aircraft Corporation.

III. USML Category XII(c) – Infrared Focal Plane Arrays, Image Intensifier Tubes, Night Vision, Electro-optic, Infrared and Terahertz Systems, Equipment and Accessories

The revised USML Category XII(c) removes "specifically designed for military applications" and develops a positive list for infrared focal-plane arrays ("IRFPAs"), image intensifier tubes, night vision, electro-optic, infrared and terahertz systems, equipment and accessories. As proposed, Category XII(c) controls technology deemed sensitive in its most basic form (e.g., IRFPAs and ROICs) while potentially releasing that same technology to the EAR if built into higher-level assemblies. UTC fundamentally disagrees with the proposed control parameters (e.g., stabilization, wavelength, and resolution) used in Category XII(c), which are not inherently military parameters and would result in capturing items in normal commercial use. Controlling IRFPAs, ROICs, gimbals, infrared imaging systems, and parts and components through non-military control parameters will have a direct, negative impact on U.S. industry competiveness in the international market as foreign manufacturers continue to expand and improve similar products with fewer restrictions. UTC recognizes the difficulty in developing positive control parameters and recommends DDTC consider the use of "specially designed" for military applications in select subparagraphs within USML Category XII(c). The sections below capture UTC's specific areas of concern with the proposed Category XII(c). Additionally, Appendix A highlights foreign camera and IRFPA sources.

A. Remove Wavelength Range as Military Control Parameter in Category XII(c)(2)

Category XII(c)(2) captures unencapsulated photon detectors, microbolometer detectors, or multispectral detector IRFPAs having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm. The infrared spectrum is not a military parameter. Commercial products and applications require the ability to sense or "see" in the infrared. One-dimensional unencapsulated IRFPAs are sold and used for commercial applications such as spectroscopy telecommunications channel monitors.

An ambiguity is also created by the reference to 'peak response' in this paragraph and many of the following paragraphs. Industry normally describes the wavelength response of photon detectors in terms of 'responsivity,' 'detectivity' or 'quantum efficiency.' For the same detector, response plot curves can have a peak (maximum) at different wavelengths. The language in the amendment needs to be modified to specify on what basis control will be determined. UTC recommends DDTC add a note to XII(c) defining and clarifying the term 'peak response.'

One-dimensional IRFPAs (i.e., linear array) consist of a PDA strip mounted next to one or two readout integrated circuits epoxied to ceramic, mounted on a TEC or copper shim, and wire-bonded to package pins. Unencapsulated one-dimensional IRFPAs are used extensively by UTC's domestic and international customers for commercial spectroscopy applications. InGaAs is the most common material used in infrared spectroscopy for studying light in the wavelength range of 900 nm to 1700 nm. Unencapsulated linear arrays are sold to OEM commercial spectroscopy system manufacturers for incorporation in LN2 or TEC vacuum Dewar assemblies or to have miniature optical spectrometer components installed within the same package as the

IRFPA with the complete assembly encapsulated as a complete fiber optic spectrometer.[7] Photoluminescence, Electroluminescence, Near Infrared ("NIR"), Fluorescence and Raman Spectroscopies, Laser Diode and fiber optic transmitter characterization, and machine vision for sorting based on the spectral features are among the most common commercial infrared spectroscopy applications. UTC is not aware of military demand or fielded military systems using unencapsulated one-dimensional arrays.

B. Delete or Amend USML Category XII(c)(3)

One-dimensional photon detector IRFPAs are in normal commercial use and the proposed detector element control parameter in Category XII(c)(3) is not a military discriminator. The subparagraph captures encapsulated one-dimensional photon detector IRFPAs that have more than 640 detector elements regardless of the pixel geometry. The current EAR controls for similar non-space qualified IRFPAs make a distinction between 1D arrays with pixel height equal or less than 3.8 times the pixel pitch (e.g., tall vs. square pixel array). Encapsulated one-dimensional photon detector IRFPAs up to 2048 detector elements are primarily used for commercial applications, including FTIR/NIR interferometry, NIR spectroscopy, biomedical analysis, and industrial process control. Most minerals contain distinct absorption features in the SWIR/NIR, making this region of the spectrum the best candidate for spectroscopic analysis in many applications. Hydroxyl-bearing minerals, sulfates, and carbonate materials produced naturally on Earth are easily identified through SWIR spectroscopy. Clays in general, like Kaolinte and Alunite, have strong absorption near 1400 nm and 2200 nm. Plastics and pharmaceuticals can be sorted based on spectral features between 1100 and 2500 nm. These are primarily commercial applications. UTC does not advertise/market encapsulated one-dimensional photon detector IRFPAs for non-commercial applications because there is limited military demand.

Typical military applications for surveillance, field laser detection, fire control, and targeting, are not using one-dimensional IRFPAs because they have lower sensitivity than two-dimensional detectors. As an example, when the one-dimensional detector exposure time is set for sensitivity similar to that of a typical two-dimensional detector, the acquisition time for a useful image is 100 to 1000 times longer for a one-dimensional detector when compared to a two-dimensional detector (depending on the number of lines in the image). For a sensitive exposure time used for a 30 fps 2-D detector, using the same exposure time for one line time would result in 30 times less sensitivity and, if there were 100 lines in the image height, the frame time would be 3.3 seconds. For most military purposes that frame rate would be unusable.

Since 2003 when 1024-pixel arrays were first offered, military end users or related organizations accounted for only 1.9% of UTC sales of one-dimensional photon detector IRFPAs with more than 640 detector elements. Additionally, just over 20% of sales of encapsulated one-dimensional IRFPAs that have 1024 pixels were for export (see Figures 2 and 3 below).

[7] Supporting sales data is UTC Aerospace Systems' Proprietary and can be provided to the U.S. government upon request.

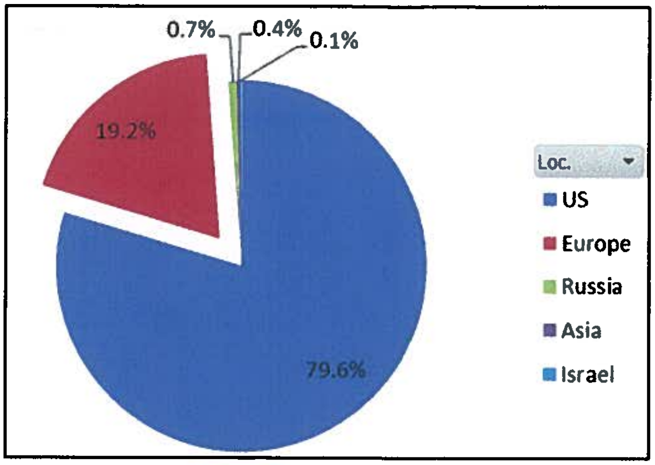

Figure 2 - 1024 pixel Linear Array Total 2003 to 2015

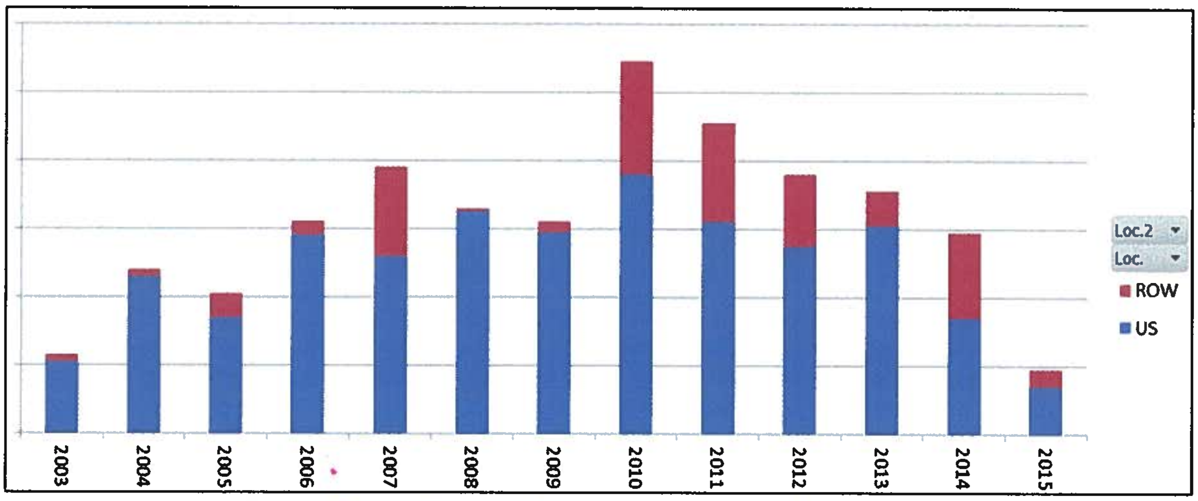

Figure 3 – 1024 Linear Array Sales: U.S. vs. Rest of World ("ROW")

UTC recommends that DDTC delete Category XII(c)(3) due to the overwhelming commercial nature of one-dimensional photon detector IRFPAs with more than 640 detector elements and peak response in the 900nm – 2500nm wavelength range. These items should continue to be controlled under the EAR and the current EAR 6A002.a.3.d.2.a control parameters should remain unchanged. If the Department determines that there is a need to maintain Category XII(c)(3), UTC urges DDTC to control only "specially designed" permanently encapsulated one-dimensional photon detector IRFPAs described in paragraph (c)(2) of Category XII. Using "specially designed" is the only meaningful way to distinguish between commercial and military items. The number of pixels (e.g., 640 detector elements) is an arbitrary, non-military parameter and should not be used as it captures items in normal commercial use.

C. Eliminate Pixel Count Control Parameter for USML Category XII(c)(4)

Category XII(c)(4) controls two-dimensional encapsulated IRFPAs with 256 elements. This control parameter appears to be an arbitrary application of resolution that does not adequately distinguish between military and civil applications. Civil applications include laser beam profiling, thermal imaging through glass, NIR spectroscopy-based inspection imaging, microscopic inspection of silicon integrated circuits, and for biomedical research.

InGaAs arrays with greater than 256 elements are in global commercial distribution. Hamamatsu (Japan)[8] sells 64x64 and 128x128 arrays, and SCD (Israel)[9], NIT (France)[10], Sofradir (France)[11], and ChungHwa (Taiwan)[12] sell 320x256 and 640x512 InGaAs arrays. The proposed controls in Category XII(c)(4) are not consistent with the control parameters in Category XII(c)(5), which releases encapsulated microbolometers up to 640x512 pixel formats to the CCL. Using resolution as a military control parameter results in ITAR-control for components that are in normal commercial use and available world-wide through foreign competitors. Appendix A provides an overview of foreign manufacturers.

UTC recommends DDTC eliminate the number of pixels (i.e., 256 elements) as a control parameter and revise Category XII(c)(4) to control two-dimensional encapsulated IRFPAs "specially designed" for military applications.

D. Revise USML Category XII(c)(6)

This control captures multispectral IRFPAs in a permanent encapsulated sensor assembly having a peak response in any spectral band within the wavelength range exceeding 1,500 nm but not exceeding 30,000 nm. UTC understands that this captures IRFPAs in EO/IR systems with SWIR payloads and that such payloads are included in EO/IR systems on commercial helicopter models be being used for civil SAR. The civil SAR role is discussed in Section III (G). The "specially designed" (b)(3) release is not available. Additionally, this paragraph is not covered by Note 2 to paragraph (c) that identifies conditions under which certain articles are EAR-controlled when integrated into items subject to the EAR. Therefore, other than the commodity jurisdiction process, there is no opportunity for these items transitioning to the CCL.

E. Clarify USML Category XII(c)(7)

Category XII(c)(7) controls charge multiplication focal-plane arrays that have more than 1,600 elements in any dimension. For a planar array, this could be interpreted to be the diagonal dimension. A square array that is 1132 elements on a side would have 1600 elements measured diagonally. DDTC may not have intended to control these types of arrays. If these arrays are inadvertently controlled by the new XII(c)(7), UTC recommends clarification by stating that the control is based on having more than 1,600 elements along any edge dimension.

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[8] See http://www.hamamatsu.com/eu/en/product/alpha/I/4007/4002/4205/index.html
[9] See http://www.scd.co.il/
[10] See http://www.niteurope.com/
[11] See http://www.sofradir.com/technology/ingaas/
[12] See http://www.leadinglight.com.tw/

F. Revise USML Category XII(c)(9)(i)

This control captures integrated IRFPA Dewar cooler assemblies having cryocoolers with a cooling source temperature below 218K and a mean-time-to-failure in excess of 3,000 hours. UTC understands that this criteria will capture Dewar cooler assemblies contained within certain EO/IR systems on commercial helicopter models be being used for civil SAR. The civil SAR role is discussed in Section III (G). The "specially designed" (b)(3) release is not available and this paragraph is not covered by Note 2 to paragraph (c). Therefore, other than the commodity jurisdiction process, there is no opportunity for these items transitioning to the CCL. UTC requests that this control be revised to cover only IRFPA Dewar cooler assemblies that have unique military application.

G. Revise Gimbal and Infrared Imaging System Controls in USML Category XII(c)(10)-(11) and XII(c)(16)(i)

The revised control parameters for gimbals and infrared imaging systems in USML Category XII(c)(10)-(11) and XII(c)(16)(i) use root-mean-square ("RMS") stabilization, number of axes of active stabilization, and, in some instances, whether they are "specially designed" for items controlled under the USML. The two positive control parameters (i.e., RMS stabilization and axes of active stabilization) should not be used as military performance discriminators. The parameters are not inherently military, control EO/IR and EO-only gimbals and imaging systems that are in normal commercial use, and EO/IR and EO-only gimbals and imaging systems that are available from foreign manufacturers. EO-only and EO/IR gimbals and image systems are used to fit a wide range applications for manned and unmanned systems, providing real-time imagery for ISR, law enforcement, civil SAR, aerial firefighting, aerial surveying, infrastructure inspection, pipeline and utility surveillance, mapping, surface vehicles and atmospheric sciences.

UTC recommends DDTC avoid using control parameters with no clear military bright line (e.g., stability), but develop positive ITAR-control parameters focused on payloads and functions that make a gimbal/imaging system inherently military. There are certain IR system functions that are exclusively military and should remain ITAR-controlled. The proposed revision to Category XII appropriately includes the following function-based capture criteria:

- Automated missile detection or warning;
- Hardening to withstand electromagnetic pulse (EMP) or chemical, biological or radiological threats;
- Incorporation of mechanisms to reduce signature; and
- Incorporation of an IT beacon or emitter specially designed for IFF.

UTC recommends including the following features that may better distinguish military systems and equipment that warrant control on the USML:

- Laser target-designator payloads that are compatible with laser-guided munitions;
- Integration of EO/IR systems with weapons;

- Incorporation of countermeasures not listed above (e.g., protective filters); and
- Ability to simultaneously track multiple targets.

Category XII(c)(10) controls gimbals with two or more axes of active stabilization having a minimum RMS stabilization better than 200 microradians and "specially designed" for articles controlled on the USML. Certain items may transition to the CCL in situations if the gimbal meets the "specially designed" release provisions of Section 120.41(b). The same "specially designed" language is not used in subparagraph XII(c)(11) for gimbals with two or more axes of active stabilization and minimum RMS stabilization better than 100 microradians. The gimbals in XII(c)(11) are controlled because of a stabilization level used in commercial and foreign available systems (see Table 1 below).

Category XII(c)(16)(i) enumerates additional controls for infrared imaging systems incorporating or specially designed to incorporate a USML XII article, having two or more axes of active stabilization, and a minimum RMS stabilization better than 200 microradians. This proposal appears duplicative of Category XII(c)(10) and introduces confusion over proper classification. The level of stabilization of an IR imaging system is again used as a military control parameter. "Specially designed" is invoked at the system and equipment level when the system or equipment is specially designed to incorporate articles controlled in Category XII. IR imaging systems or equipment in commercial use may continue to be subject to ITAR control.

UTC respectfully requests DDTC review foreign availability information for gimbals and infrared imaging systems before finalizing control parameters that may continue to hinder U.S. industry. Table 1 highlights foreign gimbal manufacturers that develop, market, and sell non-ITAR controlled EO/IR gimbal systems with performance that significantly exceeds DDTC's current proposal. Some of the systems, as noted below, have stabilization levels better than 20 microradians.

Table 1 - International Gimbal Manufacturers

Company	Country	Product	Manufacturers Product Information
Controp	Israel	U-STAMP and D-STAMP	http://www.controp.com/default.asp?catid={0560E7DD-45DB-4E27-AD8B-6A2A94271256}&details_type=1&itemid={2B40E626-2160-49E0-9378-E3AADD46D8BF}
IAI - Tamiam	Israel	POP-family of gimbals	http://www.iai.co.il/2013/18688-16661-en/IAI.aspx
SweSystem	Sweden	Seven gimbal options with 4-5 axis stabilization and up to ~ 15 mrad stabilization	http://www.swesystem.se/products.html
PolyTech	Sweden	Long range and compact systems	http://www.polytech.se
Micropilot	Canada	MP-DAY/NIGHTVIEW	http://www.micropilot.com/products-cameras.htm
Integrated	Pakistan	Three stabilized	http://www.idaerospace.com

Dynamics Aerospace		camera gimbals in the same size class as TASE family	
DST Control	Sweden	OTUS family of gimbals	www.dst.se
PEIPORT	Hong Kong	SkyEye 2X with 4 active-axis and less than 20 microradians stabilization	http://www.peiport.com/download/Gimbals/Catalog/2X_EN.pdf
M-TEK	South Africa	Four axis stabilized gimbal	http://www.mtek.co.za/products/positioners/four-axis-gimbals-for-stabilized-systems/
UAV Vision	Australia	Three EO/IR gimbals	http://uavvision.com/product-cat/gimbals/
Xenics	Belgium	Pumair EO/IR gimbals	http://www.xenics.com/en/pumair

UTC is specifically concerned that the proposed controls will hamper sales of U.S.-origin EO-only and EO/IR gimbals, IR imaging systems, and commercial helicopter sales. Commercial helicopter applications require performance well beyond the proposed ITAR-controls as detailed below.

Commercial Helicopter Applications

Gimbals with 2 or more axes of active stabilization with performance significantly better than 200 microradians are currently used in EO/IR systems on civil helicopter platforms for non-military applications. The stabilization performance of some gimbals being used for non-military purposes is 5 microradians. Table 2 provides examples of non-military applications where the stabilization is significantly better than 200 microradians. These examples reflect the use of EO/IR sensor systems on the Sikorsky S-92 helicopter and the S-76 helicopter, which are both civil model helicopters. The helicopters in the examples are being operated for civil Search and Rescue ("SAR").

Table 2 – Commercial SAR Platforms/Civil SAR Applications

Model	Contractor	Mission	EO/IR System[13]
S-92	Bristow	U.K. Coast Guard	FLIR Systems, Inc. 380-HD
S-92	CHC	Irish Coast Guard	L3 Wescam MX-15
S-76	N/A	Japan Coast Guard	FLIR Systems, Inc. Star Safire HD

Civil SAR is becoming more prevalent around the world as countries (e.g., United Kingdom) are deciding to contract with civilian organizations to provide civil SAR services.[14] Some governments do not have helicopter SAR capability. In the off-shore oil and gas arena there are some companies establishing organic SAR capability. These companies are contracting with civilian helicopter operators or are equipping their own aircraft to establish civil SAR capabilities.

[13] Listed model designations are not necessarily the full model designation.
[14] The Bristow Group is an example of civilian organization providing civil SAR services: http://bristowgroup.com/helicopter-services/uk-sar/uk-sar-awards/

Improved levels of stabilization contribute to enhancing SAR operational capability and increase the probability of successful mission outcomes. Higher levels of stabilization translate to lower levels of image jitter, which provides better image quality particularly at longer ranges. In addition, improving the ability to discern obstacles in low light and/or low visibility, particularly at low altitudes, reduces operational risk to aircraft and crew.

Sophisticated EO/IR systems are manufactured worldwide. A number of foreign manufacturers advertise EO/IR systems with stabilization better than 25 microradians. See Table 3 for additional foreign availability information for IR imaging systems.

Table 3 – Foreign Available EO/IR Systems

System[15]	Manufacturer	Country	Resolution (Thermal Imager)	Stabilization (lower values reflect higher performance)
MX-15[16]	L3 Wescam	Canada[17]	640 x 512	<5 (typically)
Toplite EOS[18]	Rafael	Israel	640 x 512 or 1280 x 1040	<25 µrad
Agile 2[19]	Thales Optronique	France	320 x 240 or 640 x 512	3 axis
Euroflir 350[20]	Sagem	France	680 x 512	4-axis stabilized gimbal
MOSP3000-HD[21,22]	IAI	Israel	1280 x 1024	<25 µrad
DCoMPASS[23]	Elbit Systems	Israel	640 x 512	Stabilized system
EOST-46[24]	Selex ES	Italy	640 x 512	≤20 µrad
275-HD[25]	FLIR Systems, AB	Sweden	640 X 512	4 axis active stabilization

[15] The table relies primarily upon manufacturer's information available on the Internet.
[16] See http://www.wescam.com/wp-content/uploads/PDS-MX-15-63133M-July-2014.pdf
[17] ITAR controlled. Sikorsky understands that the system contains a number of U.S. components.
[18] See http://www.rafael.co.il/marketing/SIP_STORAGE/FILES/8/1278.pdf
[19] See https://www.thalesgroup.com/en/worldwide/defence/agile-2-and-agile-4-electro-optic-turrets
[20]See www.sagem.com/file/download/d1650e_euroflir_350.pdf
[21] IAI: http://www.iai.co.il/2013/18688-16667-en/IAI.aspx
[22] Helicopter Multi-mission Optronic Stabilized Payload (HMOSP) indicates stabilization better than 25 µrad and resolution of 320 x 240.
[23] Elbit brochure currently not available online.
[24] See http://www.selex-es.com/-/eost46-1
[25] See http://www.flir.com/uploadedFiles/flirGS/Surveillance/Products/Star_SAFIRE_HD_Family/Star_SAFIRE_HD_Family/275-HD/flir-star-safire-275-hd-datasheet-ltr.pdf

350-HD[26]	FLIR Systems, AB	Sweden	640 X 512	4 axis active stabilization

Sikorsky uses EO/IR systems on its SAR-configured commercial helicopters that are presently captured in USML Category XII(c). When these ITAR-controlled EO/IR systems are installed on a commercial helicopter, the aircraft as a whole is captured in USML Category VIII(a)(11) which controls aircraft incorporating ITAR-controlled missions systems. ITAR licensing is often viewed in a negative light when competing directly against foreign manufacturers/providers in international markets.[27]

UTC recommends that the U.S. government control gimbals and infrared imaging systems that are "specially designed" for military use defined by functions that are peculiarly military functions (e.g., laser target designator payloads compatible with laser guided munitions, integration of weapons systems, and implementing counter measures) on the ITAR. All other infrared imaging systems and gimbals should be controlled on the CCL under ECCNs 6A003 and 6A004, respectively. ECCN 6A003 and 6A004 are subject to National Security (NS Column 2) control, and ECCN 6A003 is also subject to Nuclear Nonproliferation (NP) and Regional Stability (RS) controls.

This proposal is consistent with internationally recognized military and dual-use control parameters found in the Wassenaar Arrangement Munitions and Dual-Use List. Gimbals are specifically enumerated by the WA Dual-Use List in 6.A.4.d.3 and include specific control parameters. Infrared imaging or countermeasure equipment that is specially designed for military use is controlled by the WA Munitions List in ML15. This proposal will allow U.S. industry to remain competitive with foreign manufacturers and still protect items that provide unique military or intelligence advantages.

H. Revise Camera Core Controls in USML Category XII(c)(12)

USML Category XII(c)(12) controls infrared-imaging camera cores and specially designed electronics and optics with certain criteria, but there are no clear military control parameters. Subparagraphs XII(c)(12)(v) and XII(c)(12(vii) control commercially-available, unencapsulated and encapsulated one-dimensional photon detector IRFPAs as previously described in Section III(A)-(B) of this document despite being assembled in a higher-level assembly that is in broad, global distribution. Figure 4 shows UTC booking history for linescan cameras (e.g., packaged in enclosures without lenses and requiring connection to computers to process line data to form and display images).[28]

[26] See http://www.flir.com/uploadedFiles/flirGS/Surveillance/Products/UltraForce_350-HD/flir-ultraforce-350-hd-datasheet-ltr.pdf
[27] Sikorsky intends to provide additional, proprietary information to the U.S. government.
[28] Detailed supporting sales data is UTC Aerospace Systems' Proprietary and can be provided to the U.S. government upon request

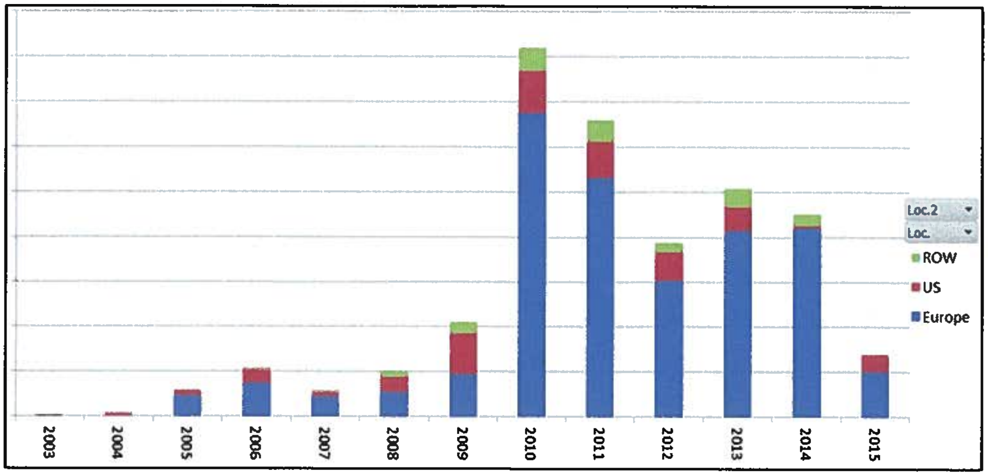

Figure 4 – UTC Sales of Linescan Cameras Greater than 640 Pixels

Historically, UTC linescan cameras were commercially available for both spectroscopy applications (with tall pixels with height of >3.8 times the pixel pitch) and for machine vision (square pixels). Machine-vision applications for inspecting hollow glass bottles and silicon for solar cells have driven a much larger market for InGaAs linescan cameras than for spectroscopy cameras (see Figure 5).

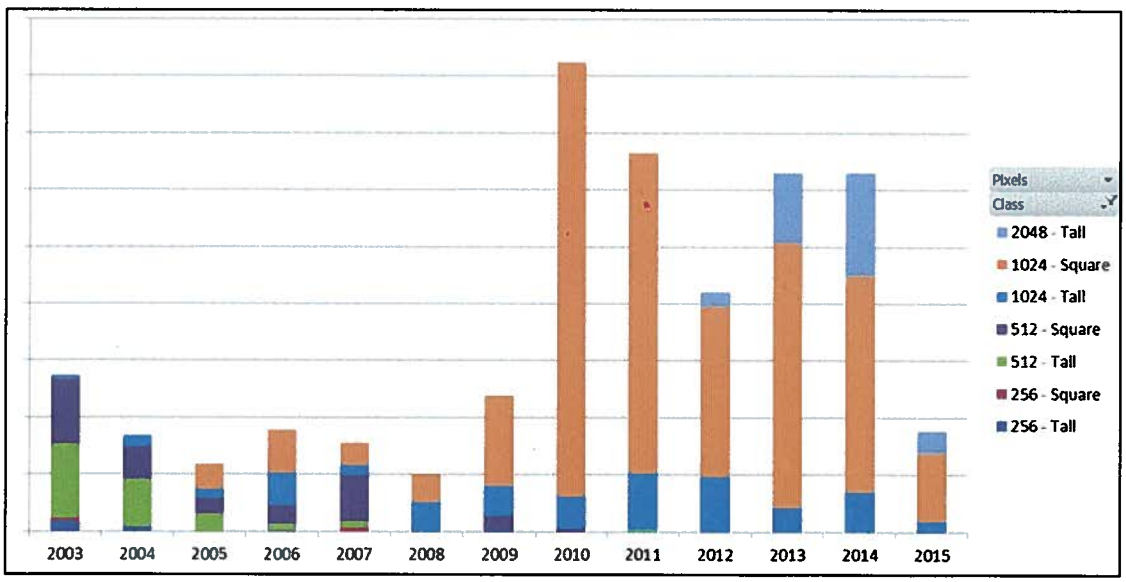

Figure 5 – Linescan Cameras by Pixel Count (2003-2015)

As with most technical markets, the data for linescan cameras shows the progression of markets moving from low-resolution to high-resolution. There have been very few sales to governmental labs or military contractors for any of the above cameras (0.3%).

DDTC defines a camera core as having sufficient electronics to enable as a minimum the output of an analog or digital signal once power is applied. It is not clear at what point a camera core becomes a fully-packaged camera controlled in Category XII(c)(16). The control for linescan cameras is ambiguous as they have an output but cannot form an image without external computer processing. At what point would a linescan camera with an IRFPA be controlled by Category XII(c)(12) or transition to be an imaging system under Category XII(c)(16)? The proposed language does not address this issue. As many of the bio-medical system integrators for 1024- and now 2048-pixel linescan cameras are outside the United States, controlling these cameras as SME, particularly when there is no military-related market for them, will significantly hurt U.S. competitiveness. UTC requests DDTC amend the note to paragraph (c)(12) to make this distinction.

I. Clarify Weapon Shock Control Parameter

The weapon shock control parameter in USML Category XII(c)(12)(ii) is unclear. Does the control require a camera core to provide output imagery during the shock events or be capable of surviving more than 20 shock load events of 325 G and then provide output imagery? UTC requests DDTC clarify the control via a note to paragraph (c)(12)(ii). Additionally, the shock criteria does not establish a unique military requirement as telecommunication components, which typically use IRFPAs proposed for control in this category, require more robust industry requirements established by the Telcordia organization. Under their reference standards GR-1221 and GR-1209, components must survive 5 shocks per axis of 500 G of 1 ms duration on each of 6 directions, for a total of 30 shocks.[29] Thus, most linear-array detectors built for commercial optical channel monitoring will pass the criteria established in the proposed amendment.

J. Modify USML Category XII(c)(12)(viii)

UTC agrees with DDTC in Category XII(c)(12)(viii) that camera cores having two-dimensional photon detector IRFPAs with a peak response wavelength range exceeding 900 nm but not exceeding 2,500 nm and less than 111,000 detector elements do not warrant ITAR control because they are in normal commercial use and are inadequate for most military uses. Camera cores utilizing two-dimensional photon detector IRFPAs with greater than 111,000 detector elements are used for both military and commercial applications and should be controlled by the CCL. A list of commercial and dual use applications for camera cores utilizing two-dimensional photon detector IRFPAs are listed below:

[29] The Telcordia website includes the commercial standards referenced above. The abstracts can be found at: http://telecom-info.telcordia.com/site-cgi/ido/docs.cgi?DOCUMENT=1221&KEYWORDS=&TITLE=&ID=254735397SEARCH

- Driver Vision Enhancement
- Aircraft Enhanced Vision System
- Security
  - Perimeter
  - Border Security
  - Bridge/Port
  - Highway monitoring
- Enhanced Flight Vision Systems
- Adaptive Optics
- Telecommunications
  - Laser beam profile
- Thermal Measurements (above 100°C)
- Inspection/Sorting
  - Agricultural Products
  - Plastic Sorting
  - Semiconductors (1280x1024)
  - IC inspection (1280x1024)
  - Solar Cell/Si Ingot
- Spectroscopy (multi/hyper spectral)
- Medical Imaging
  - Optical Coherence Tomography
  - Dental Transillumination
- Infrared Reflectography
  - Ancient Artwork

UTC recommends DDTC revise the language in Category XII(c)(12)(viii) to control only camera cores utilizing two-dimensional photon detector IRFPAs with greater than 330,000 detector elements that are "specially designed" for military applications. Camera cores with less than 330,000 detector elements and camera cores that are not "specially designed" for military applications should be controlled on the CCL.

There are a number of international sources manufacturing, marketing, and selling non-ITAR controlled cameras and camera cores that exceed DDTC's proposed control parameters. Manufacturers are located in Japan, United Kingdom, Germany, Austria, Israel, France, Belgium, Taiwan, Turkey, and China (see Appendix A).

K. Clarify XII(c)(16)(iii)-(iv)

Subparagraphs XII(c)(16)(iii)-(iv) control infrared imaging systems or equipment that have greater than 640 detector elements in any dimension. UTC recommends clarification by stating that the control is based on having more than 640 elements along any edge dimension. As discussed in previous sections, the use of resolution or element count as a demarcation between military and civil applications is flawed as the technology is inherently civil or dual-use.

The proposed change in Category XII(c)(16) will control UTC's SU1024 and GL2048 pixel linescan (one-dimensional) camera families[30] that are in regular commercial use. These digitally-interfaced cameras require machine-vision interfaces (e.g., Camera Link), external computers with displays, and civil-oriented spectroscopy and/or machine vision software to be useful. The development of each generation of these cameras was driven by a medical application called Optical Coherence Tomography ("OCT"). OCT is a technique used to capture microscopic images of the front and back surfaces of the eye. The basic technique is used for eye diagnostics and thin-film industrial measurements for over a decade. Imaging with infrared wavelengths permits deeper imaging in tissue. The medical application drives the development of high line rates in order to capture 3-D volumes between eye movements while imaging the whole retina and to map blood flows in the tissue. Customers include global medical researchers, industrial instrumentation companies, and system manufacturers servicing those applications.

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[30] See http://www.sensorsinc.com/products/linescan-cameras/

There was no U.S. government or military funding for development and only 0.3% of camera sales were to related organizations. The technology and resultant imaging systems are commercial.

Establishing ITAR controls for these commercial items will negatively impact global competiveness as the ITAR requirements will significantly increase the complexity of the transactions. As an example, UTC customers (e.g., U.S. research institutions) employ and/or train non-U.S. persons. The proposed controls will also discourage U.S.-based system integrators that export their systems. Foreign manufactures have 2048-pixel linescan cameras and IRFPAs and 1024-pixel arrays/cameras (see Appendix A). UTC competiveness will be seriously impacted by the proposed amendment, ceding current U.S. manufacturing advantages to non-U.S. manufacturers. Without competitive access to such markets, there will be insufficient return on investment to sustain U.S. competitive advantages in low-dark-current, low-noise photodetectors.

L. Possible Issue with XII(c)(16)(v)

Related to UTC's earlier comments on Category XII(c)(6), UTC understands that this paragraph captures EO/IR systems with SWIR payloads and that such payloads are included in EO/IR systems on commercial helicopter models used for civil SAR. The civil SAR role is discussed in Section III (G). The "specially designed" (b)(3) release is not available as this is a system level control. There are foreign available systems that incorporate SWIR payloads into non-ITAR EO/IR systems.[31]

M. Positive Military Control Parameters - XII(c)(16)(vi)-(vii) and XII(c)(20)

UTC agrees with DDTC on the positive, military control parameters specifically enumerated in subparagraphs XII(c)(16)(vi)-(vii) and XII(c)(20)-(21). Infrared imaging systems that include automatic missile detection or warning and/or hardened to withstand electromagnetic pulse or Weapons of Mass Destruction threats have little to no commercial application and DDTC clearly established a positive bright line for military applications. Additionally, systems that incorporate an IR beacon or emitter for friend or foe identification are also inherently military or intelligence articles.

N. Signature Reduction Control Parameter in XII(c)(16)(viii)

Category XII(c)(16)(viii) controls infrared imaging systems or equipment incorporating mechanisms to reduce signature without defining what kind of signature or what level of signature reduction is controlled. As an example, insulation that provides audible noise reduction may qualify as signature reduction or an item that has thermal insulation to provide internal temperature stabilization that unintentionally results in a thermal signature closer to the background may be controlled without additional clarity to this entry.

[31] See http://www.xenics.com/en/pumair-170dw

O. Department of Defense Funding for Developmental Imaging Systems or Equipment

UTC respectfully requests DDTC work with the Department of Defense on the implications of Note 1 to paragraph XII(c)(21). The presence of DOD funding for developmental imaging systems or equipment operates as a "catch-all" control, and requires contractors to either obtain a CJ determination or ensure the relevant government contract or funding authorization explicitly identifies the items as being developed for both civil and military applications. The contracting process is often complex and time-constrained, and contracting officers are not always familiar with the implications that language in the funding documents can have on the jurisdiction of products. In order to invoke control under Category XII(c)(21), DOD should be required to affirmatively enumerate in the contract or other funding authorization documents those developmental items that are subject to the ITAR.

P. Tamper Proofing Requirements in Note 2 to Paragraph (c)

The current language in USML Category XII(c) includes a carve-out for military second- and third-generation image intensification tubes and military infrared focal-plane arrays to be licensed by the Department of Commerce when incorporated into a commercial system. Note 2 to Paragraph (c) in the proposed rule includes a similar carve-out but adopts burdensome tamper-proofing requirements. Items controlled by the subparagraphs in the proposed Category XII(c) are only eligible for the carve-out if the items cannot be removed without destruction or damage to the article or render the item inoperable. Imposing new tamper-proofing requirements on U.S. industry will create unintended consequences, including increased product costs, development time, and repair issues. UTC recommends DDTC remove the tamper-proofing language in Note 2 to Paragraph (c).

Q. Create Space Qualified FPA and ROIC Reference in Note 3 to Paragraph (c)

The proposed Category XII(c) does not make a distinction between space and non-space qualified IRFPAs and ROICs. UTC recommends this distinction be made through a new note to Paragraph (c). Space-qualified FPAs and ROICs are currently controlled in USML Category XV(e)(3). Adding this reference will make Category XII more consistent with the control language and delineation between space- and non-space qualified FPAs and ROICs found in the CCL and Wassenaar Arrangement's Dual-Use List.

IV. <u>USML Category XII(d) – Guidance, Navigation, and Control Systems and Equipment</u>

A. Clarify Amendment to VIII(e) and Note to (d)(1)

The Note to (d)(1) points to USML Category VIII(e) for aircraft and unmanned aerial vehicle guidance or navigation systems. The proposed Amendment to USML Category XII also includes an Amendment to Category VIII by removing and reserving paragraph (e). The implications of the Amendment to Category VIII and Note to (d)(1) are not clear. UTC requests DDTC address whether all guidance, navigation, and control systems and equipment that meet the stated control criteria for aircraft or UAVs are now to be controlled in Category XII(d).

V. USML Category XII(e) – Parts, Components, Accessories, Attachments, and Associated Equipment

UTC supports DDTC's effort to develop a revised, positive list for parts, components, accessories, attachments, and associated equipment in Category XII(e). A positive Category XII(e) that specifically enumerates items for control allows non-sensitive items to move to the EAR. UTC identified parts and components (e.g., mechanical parts for imaging system) that do not directly interface with the core technology of controlled systems that should no longer be ITAR controlled under the revision to Category XII(e).

A. Tamper-Proofing Requirements in Note 1 to Paragraph (e)

Note 1 to paragraph (e) states that articles described in Category XII(e) are subject to the EAR when integrated into and included as an integral part of an item subject to the EAR and cannot be removed without destruction or damage to the article or render the item inoperable. The reasoning for including tamper-proofing language for parts, components, accessories, attachments, and associated equipment is not clear. Imposing tamper-proofing requirements on U.S. industry may create unintended consequences, including increased product costs, development time, and repair issues. Additionally, the requirement to control technical data associated with integrated parts, components, accessories, attachments, and associated equipment as ITAR even if the hardware is no longer subject to the ITAR is overly complex. This may require a U.S. exporter to obtain two licenses: a Commerce Department license for hardware/higher level assembly and a State Department license for technical data associated with an integrated part/component. UTC requests DDTC remove the tamper-proofing language in Note 1 to Paragraph (e) and reconsider the requirement to control technical data associated with integrated parts and components under the ITAR.

B. Delete USML Category XII(e)(3)

Wafers are controlled by Category XII(e)(3) if they incorporate structures for either a ROIC controlled in paragraph (e)(4)-(5) or an IRFPA or detector elements controlled in paragraph (c)(2). The term "structures" requires clarification to properly articulate what level of processing qualifies as a controlled structure. The parameters in Category XII(c)(2) control IRFPAs and ROICs that are in normal commercial use. This proposed control places an undue hardship on U.S. industry and limits the ability to work with non-ITAR foundries for currently EAR-controlled ROICs and photodiode wafers. ITAR foundries are significantly more expensive due to limited volume and increased compliance documentation costs. Epitaxy wafers for InGaAs/InP detector elements are mostly made by non-U.S. sources.

ROIC and photodiode wafers and the structures on them do not in and of themselves generate uniquely military performance level imagers. The manufacturer's proprietary designs, device operating and processing methods have key impact on device performance. ROIC and photodiode wafers and the structures on them do not provide the keys for producing uniquely military performance level imagers that would be considered U.S. "crown jewel" technology. Manufacturers' proprietary structure designs and processing methods have more impact on device performance. These aspects cannot be simply reversed engineered by persons in possession of complete or partially assembled devices. Mapping the material concentration layers in the photodiodes or the connection nodes of ROICs does not disclose the necessary information to achieve commercial or military performance levels for IRFPA imaging.

Current restrictions on IRFPA-based products induced foreign governments (e.g., France, Taiwan, and Korea) and regional organizations (e.g., EU and ESA) to fund foreign commercial companies (e.g., Xenics, Acatel-Thales, Mikro-Tasarim, Chunghwa, and Kyosemi) to develop indigenous capability and improve photodetectors, both for commercial telecom and general imaging applications. Detector technology is primarily driven by fiber optic telecommunication needs and products are fabricated globally. Added controls on wafers for imaging photodiodes and ROICs will further hinder U.S. companies while providing added incentive to foreign entities to improve their capabilities. Wafers for IRFPA photodiodes and ROICs should not be specifically enumerated in Category XII(e) and UTC recommends that DDTC delete Category XII(e)(3).

C. ROIC Control Issue with Category XII(e)(4)(ii) and XII(e)(5)

Category XII(e)(4) and XII(e)(5) effectively control all one-dimensional ROICs that are currently used in IRFPAs for commercial cameras or spectrometers. The ROICS are in volume production for the SWIR band for commercial and civil applications as shown in Sections III (B) and (E) of this document. One-dimensional ROICs differ from two-dimensional ROICs as the readout circuitry is simpler, while having to work with larger photodiode sizes that result in lower sensitivity. One-dimensional ROICs also are designed to support long integration times for spectroscopy and much higher readout rates that support high-speed bio-medical applications and were controlled as non-ITAR since the early 2000s. The proposed amendment places a heavy burden on U.S. industry with increased documentation and technical data compliance costs and requires the use of more-expensive ITAR-qualified fabrication and design resources. It is not clear what perceived impact on U.S. national security and regional stability warrants this level of control. UTC recommends deletion of paragraph XII(e)(4)(i).

Subparagraph XII(e)(4)(ii) controls 2-D ROICs with more than 256 elements. This requires ITAR handling of ROIC designs of IRFPA array formats of 2x128 or 16x16 elements. This proposed resolution control is not consistent with subparagraph XII(e)(iii), which permits microbolometers up to 640x512 to be handled under EAR controls. Recent Commodity Jurisdiction determinations have also moved InGaAs formats of up to 640x512 pixels to be controlled under the EAR. Resolution is a poor determinant of detector technology to be controlled, but if used, should recognize that technology evolves across wavelength bands. UTC respectfully requests similar resolution control parameters be applied and a mechanism to review and adjust the threshold periodically should be implemented as technology and commercial markets change.

The Note to subparagraph XII(e)(4) states that ROICs are considered "specially-designed" for IRFPAs and, therefore, are controlled under the ITAR even if the 'detector' is not incorporated in an item on the USML. The move to control subcomponents of inherently dual-use technology as ITAR appears to contradict the goals of ECR by controlling items in normal commercial use and production.

D. Delete or Revise Category XII(e)(7)(i)

UTC's earlier comment relative to Category XII(c)(9)(i) expressed the understanding that integrated IRFPA Dewar cooler assemblies having cryocoolers with a cooling source temperature below 218K and a mean-time-to-failure in excess of 3,000 hours describes assemblies contained within certain EO/IR systems used on commercial helicopters. These particular helicopters are being used for civil SAR. Accordingly, UTC requests that the assemblies and parts and components for the assemblies captured by Category XII(e)(7)(i) not be enumerated on the USML. The civil SAR role is discussed in Section III (G).

E. Delete or Amend USML Category XII(e)(9)

Infrared lenses, mirrors, beam splitters or combiners, filters, and treatments and coatings are not military parameters for control. Infrared lenses may be purchased worldwide. Lenses are typically standard offerings with infrared cameras, which now may be captured in Category XII(c). DDTC recently issued Commodity Jurisdiction (CJ) determinations that some infrared lenses are subject to the EAR. The proposed control in Category XII(e)(9) is not consistent with recent CJ final determinations. Additionally, filters may be required specifically for commercial applications. As an example, a 1400 nm bandpass filter may be used with InGaAs cameras to observe water absorption spectrum response range. This filter is not related to a military application or end use. UTC recommends DDTC revise Category XII(e)(9) so that it does not control items in normal commercial use.

F. Clarify Multi-sensor Fusion Definition

The note to Category XII(e)(11)(ii) defines multi-sensor fusion as automatically combining imagery or information from two or more sensors, including at least one article controlled in USML Category XII, to improve classification, identification, or tracking of targets relative to any of the individual sensors. Category XII(e)(11)(ii) excludes image blending from this control but does not explain the difference between image blending and multi-sensor fusion. UTC recommends DDTC add clarifying language to Note to Category XII(e)(11)(ii) on the term "image blending." USML Category XII enumerates multi-sensor fusion prior to Category XII(e) and DDTC should consider relocating the definition/explanation earlier in the entry.

VI. <u>USML Category XII(f) – Technical Data Considered SME</u>

The revision to USML Category XII(f) controls technical data and defense services directly related to the defense articles enumerated in paragraphs (a) through (e) of Category XII as SME. UTC requests DDTC clarify this change to USML Category XII(f). The proposal seemingly requires exporters to obtain and submit a DSP-83 along with DSP-5 license applications for the permanent export of technical data. The combined effects of XII(c), (e), and (f) will burden U.S. businesses with additional paperwork and compliance costs, while restricting the ability of commercial customers with significant non-U.S. employment (e.g., research universities) to work with IRFPA-based products.

* * *

For additional information, please contact the undersigned at (202) 336-7467, peter.jordan@utc.com, or Michael Wetzel at (609) 333-8331, michael.wetzel@utas.utc.com.

Sincerely,

Peter S. Jordan
Director, Senior International Trade Counsel
United Technologies Corporation

Attachments:
Appendix A – Foreign Camera and IRFPA Sources

Appendix A - Foreign Camera and IRFPA Sources

Country	Company	Technologies	Products	Formats	Website
Belgium	**Xenics**	InGaAs	1D and 2D Cameras, Cores, IRFPAs	320x256x20	http://www.xenics.com/en/products/cameras
			(31 InGaAs variations named Bobcat, Cheetah, Rufus, Cougar, Lynx, XTM, XSW core) - Also offers cooled MCT LWIR, InSb MWIR and T2SL SWIR	640x512x20	
				640x512x25	working on 1280x1024
				512x1x25	
				1024x1x12.5	
				2048x1x12.5	
				3000x1x25	
		µBolometers	2D Cameras, Cores, IRFPAs and pan-tilt imaging systems	320x256x20	http://www.xenics.com/en/products/cameras
			(28 variations named Gobi, Raven, Meerkat, Serval, XTM core, XCO)	640x512x20	
				640x512x25	
				512x1x25	
				1024x1x12.5	
				2048x1x12.5	
		InGaAs	ROICs:		http://www.xenics.com/en/products/cameras
			2D LN2 XPA-1.7-640	640x512x20	
			1-D Xlin-1.7-512	512x1x25	
			Xlin-1.7-1024	1024x1x12.5	
			Xlin-1.7-2048	2048x1x12.5	
China	**Shanxi Guohui Optoelectrnic Technology Co. (GHOPTO)**	InGaAs	2-D Cameras	640x512x25	http://www.ghopto.com/en/index.php?m=content&c=index&a=show&catid=14&id=63
				320x256x30	http://www.ghopto.com/en/index.php?m=content&c=index&a=show&catid=14&id=64
			FPAs		http://www.ghopto.com/en/index.php?m=content&c=index&a=show&catid=14&id=65
	Debut Optoelectronic Sensors	QWIP	FPAs	640x512x25	http://www.wopuopto.com/en/about.asp?action=intro
				320x256x30	
France	**Sofradir**	InGaAs	IRFPAs Cactus 640 SW	640x512x25	http://www.sofradir.com/product/cactus-640-sw-2/
			Snake 640 SW	640x512x15	
		MCT for SWIR	IDCAs: Neptune SW/VISIR	500x256x30	http://www.sofradir.com/product/cactus-640-sw-2/
			Saturn SW/VISIR	1000x256x30	
		MCT for MWIR	IDCAs: Axir, Daphnia, Epsilon, Galatea, Inspir, Jupiter, Leo, Mars, Scorpio, Uranus MW	320x256x30/25	http://www.sofradir.com/products/?wavebands=mwir
				640x512x20/15	
				1024x768x10	
				1280x1024x15	

Appendix A - Foreign Camera and IRFPA Sources

Country	Company	Technologies	Products	Formats	Website
	New Imaging Technologies	InGaAs	2-D ROICs, Camera modules	320x256x25	http://www.new-imaging-technologies.com/ingaas-products.html
				640x512x15	
Germany	AIM INFRAROT-MODULE GmbH	MCT for SWIR	IDCAs: ActIR-1024	1024x256	http://www.aim-ir.com/en/main/products/modules.html
			ActIR-384	384x288x24	
			MW/LW	384x288x24	
			MW/LW	640x512x24/15	
			MW/LW	288x6 / 576x7	
	Allied Vision	InGaAs	Cameras G-033	640x512x15	http://www.alliedvision.com/en/products/cameras.html#spectrum/-1/maxFrameRate/-1/resolutionCalc/-1/color/-1/sensorSize/-1/sensor/-1/series/59/text//intf/-1/interfacefilter/-1/legacy//
			G-032	640x512x25	
			G-008	320x256x30	
	EHD Imaging GmbH	InGaAs	SWIR 1" format Lenses	8, 16, 25, 35, 50 mm focal lengths	http://ehd.de/products/specialapplications/NIR_Enhanced_Cameras.html
Ireland	Raptor Photonics	InGaAs	2-D Cameras – OWL	320x256x30	http://www.raptorphotonics.com/products/category/swir-vis-swir-cameras-4
				640x512x15	
Israel	SCD	InGaAs	IRFPAs, modular cores	640x512x15	http://www.scdusa-ir.com/qi-scd15-swir/
					Working on 1280
		HOT MCT, InSb, XbN	IRFPAs, modular cores named Sebastian, Kinglet, Pelican, Hercules, Blackbird	320x256x20	http://www.scdusa-ir.com/ir-sensors/
				640x512x15	
				640x512x20	
				640x512x25	
				1280x1024x15	
				1920x1536x10	
Japan	Hamamatsu	InGaAs	1-D IRFPAs (28 versions)	128x1x50	http://www.hamamatsu.com/us/en/product/alpha/I/4005/4208/4121/index.html
				256x1x50/25	
				512x1x25	
				1024x1x25 sq&tall	
			2-D IRFPAs (4 versions)	64x64x50	http://www.hamamatsu.com/us/en/product/alpha/I/4005/4208/4121/index.html
				128x128x50/20	
			2-D Cameras C10633-13, -23, 034, -50	320x256x30	http://www.hamamatsu.com/us/en/product/category/5000/5005/index.html#camera_type=0&wavelength=3
				640x512x20	
	Artray Co., LTD.	InGaAs	2-D cameras	320x256x30	http://www.artray.us/ingaas.html
				640x512x25	
				128x128x20	
Spain	New Infrared Technologies	PbSe	1-D & 2-D IRFPAs and Cores for 1 to 5 um	64x1	http://www.niteurope.com/en/tachyon-series-fpa-roic-2g.html
				32x32	
				80x80	
Taiwan	Chunghwa Leading Light Photonics Technology	InGaAs	IRFPAs	320x256x30	http://www.leadinglight.com.tw/
				640x512x25	

Appendix A - Foreign Camera and IRFPA Sources

Country	Company	Technologies	Products	Formats	Website
Turkey			2-D ROICs:		http://www.mikro-tasarim.com.tr/products
		Si, InGaAs, MCT	MT6425CA	640x512x25	
			MT6415CA	640x512x15	
			MT12815CA	1280x1024x15	
			MT20415SA	2048x2048x15	
			MT40915SA	4096x4096x15	
			MT40910SA	4096x4096x10	
		µBolometer	MT3825BA	384x288x25	
			MT3817BA	384x288x17	
			MT6417BA	640x480x17	
			MT10217BA	1024x768x17	
			MT6412BA	640x480x12	
		InSb, QWIP, MCT,T2SL (DDA designates dual direct injection array)	MT6425DA	640x512x25	
			MT6415DA	640x512x15	
			MT6410DA	640x512x10	
			MT12810DA	1280x720x10	
			MT6420DDA	640x512x20	
			MT6425DDA	640x512x25	
			MT10225DDA	1024x768x25	
		InGaAs	2-D Cameras		
			MT-USB-CAM-6415	640x512x15	
			NanoCAM-6415	640x512x15	
United Kingdom	**Defense Vision Systems Inc.**	InGaAs	2-D cameras	Same as Photonic Science	http://www.dvsmil.com/index.html
	Photonic Science	InGaAs (also offers Vis-InGaAs & >2.2um cutoff)	2-D Cameras	320x256x25	http://www.photonic-science.com/products/swir-ingaas-cameras.html#
				640x512x15	

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Office of Defense Trade Controls Policy
Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037
DDTCPublicComments@state.gov

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

Voxtel appreciates the opportunity to comment on the proposed changes to the USML. Voxtel is a company of 45 employees located in Beaverton, Oregon. Voxtel, designs and manufactures an array of laser range finding products for the commercial and defense industries.

Many US-based technology companies have invested, and are investing in consumer and industrial products which contain laser and/or LRF technology that potentially would be controlled under the proposed language of USML Category XII (b)(3). These products include eye-safe 3D cameras for autonomous vehicle navigation, geotagging accessories for smartphones and sense/avoid sensors for civil UAV's. More importantly, **all commercially available 15xxnm lasers currently used in telecommunications equipment, diagnostic instruments, surveying equipment and medical equipment would potentially be subject to ITAR control.**

To effectively market these products to international and domestic consumers requires an export classification of EAR99. This is especially the case for consumer products where export license applications for each end user is not practical.

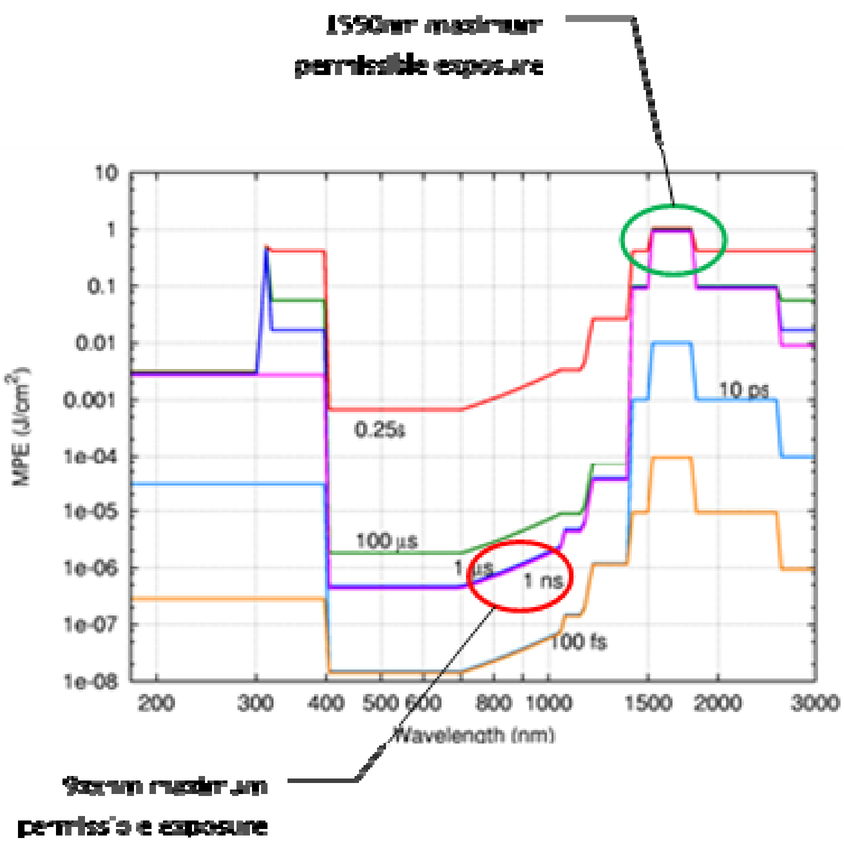
The proposed USML CAT XII (b) rule change attempts to severely restrict the type of lasers utilized in commercial laser ranging devices. The laser technologies encompassed in this expansive approach most notably include all commercially available eye-safe lasers. These lasers are ubiquitous in telecommunications, medical instruments, diagnostic instruments, surveying, traffic sensors and safety sensors.

The Department of State proposed USML Category XII(b)(3) rule would result in:

- Inadvertent control of lasers and photodiodes that are in normal commercial use
- Reduced public safety
- Control of lasers and laser rangefinders on the USML that are not controlled on the Wassenaar Arrangement's Munitions or Dual Use List.
- Generate an ambiguous line between the USML and CCL for commercial eye-safe lasers that could be used in laser rangefinders
- Restrict US companies from competing in international markets with laser rangefinder products assembled from commercially available parts
- Significant reduction in US market share for lasers exceeding 1000nm

As a glaring example, Photop Optics Co. Ltd., headquartered in Shanghai China, produces an extensive line of 1535nm, q-switched lasers (http://www.photoptech.com/main/products_jg/q_switched2.php). These COTS lasers are used in telemetry systems, remote sensing, Laser Induced Breakdown Spectroscopy instruments, 3D laser imaging systems **and laser rangefinders**.

The proposed rule language would categorically exclude eye-safe laser rangefinders for consumer purposes; the language limits lasers to wavelengths below 1000nm. Laser rangefinders are required for collision avoidance sensors, autonomous navigation, traffic control and a host of additional applications where public safety is the primary design consideration. The bulk of commercially available laser rangefinders operate in the spectrum from 905nm to 980nm. All of these devices are intrinsically an eye-safety hazard and handicapped in their performance due to the maximum permissible exposure (MPE) to human beings of the emitted laser wavelength. As described in the chart to the right, these 9xxnm devices, which typically have pulse durations in the nanosecond range, have MPE in the single digit micro-joule per square centimeter range. In stark contrast, a 1550nm laser rangefinder has a MPE in the joule per square centimeter range. In layman's terms, **the 1550nm laser rangefinders are one million times safer for humans than the 9xxnm laser rangefinders**. The eyes of infants and young children are especially sensitive to laser emmisions from 9xxnm laser rangefinders. The cornea and eye lenses of young children transmit more radiation back to the retina than for older children and adults. The dilemma presented to laser rangefinder system designers, if the proposed rule language is adopted, will be to trade off range and precision for eye-safety.



The key performance parameters for commercial, portable rangefinders are eye-safety, range, and accuracy. The key product parameters are size, weight and cost. Virtually all commercial applications have a maximum range requirement less than 2km.

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Man-portable laser rangefinders for military applications have range requirements from 3km to as much as 30km. This range performance is required under severe adverse conditions such as rain, fog, smoke and dust. Size, weight and power consumption are also significant design considerations.

The primary differentiators between commercial and military laser rangefinders are maximum range capability and extended operation in adverse conditions. Relative range capability is determined by a host of system parameters including receiver sensitivity, receiver aperture diameter and laser pulse energy. Maximum range typically has a linear relationship to receiver aperture diameter; however there is a functional limit on the reasonable size of the LRF for portable applications, effectively limiting the aperture diameter. Maximum range also has a linear relationship with laser pulse energy. Laser pulse energy is typically limited by laser gain media constraints, weight and power considerations.

Until the advent of erbium-doped phosphate glass, most man-portable LRF devices used a neodymium-doped YAG (Nd:YAG) laser emitting at 1064nm. Typical pulse energies ranged from 1mJ to as much as 1J. With the desire to emit in the short-wave infrared region of the spectrum, these lasers were combined with an optical parametric oscillator (OPO) converting the wavelength to 1550nm. This conversion process is expensive in efficiency, beam quality and weight.

An alternative 15xxnm laser gain medium technology, primarily developed for telecom fiber lasers, became available in the mid- 1980's. Erbium doped phosphate glass typically has a transition wavelength somewhere between 1.53 and 1.6 µm. Because that transition is a quasi-three-level transition, erbium-doped lasers require a significant excitation density of the erbium ions, and erbium lasers typically exhibit a high threshold pump power. The Achilles heel of the Er:glass laser is the poor thermal properties of the host glass. The poor thermal conductance limits the average power output of the laser. Typical man-portable Er:glass laser designs provide a maximum average power of 10mW or less. This limits the effective pulse energy for Er:glass, due to the 10Hz ranging rate requirement, to 1mJ of pulse energy.

The ability of a LRF to penetrate adverse conditions is directly related to the laser pulse energy. Adverse conditions attenuate the outgoing and return echo. An additional consideration is the accuracy of the LRF; accuracy has a linear relationship to the pulse duration. For all LRF receivers, there is a threshold number of photons required within a finite period of time (typically < 10ns) to achieve an accurate range result. Consequently, laser pulse peak power is the most significant parameter to achieve critical military and intelligence advantage.

Currently, Er:glass laser designs have a peak power limit of a few hundred killowatts due to the damage threshold of the glass. Nd:YAG(OPO) lasers can achieve peak power >1MW. It is informative to note that Nd:YAG(OPO) lasers are significantly more expensive and less efficient than Er:glass lasers. Hence, Nd:YAG(OPO) lasers are minimally employed in consumer products.

There are a plethora of commercially available laser rangefinders which currently use both q-switched laser sources and lasers emitting at wavelengths greater than 1000nm. Each of these products, and the lasers they incorporate, would be considered ITAR-controlled if the proposed rule is adopted. A partial list of foreign commercial LRF sources is provided in Appendix A of this document. Each of the foreign suppliers listed incorporate a q-switched, 15xxnm laser.

In addition, there is a market category of scanning laser rangefinders which also utilize q-switched, 15xxnm lasers. This market segment is bifurcated into terrestrial and airborne applications. A survey of the commercial airborne products is listed in Appendix B.

A partial list of foreign countries which maintain companies that commercially market laser rangefinders with q-switched lasers or lasers with wavelengths greater than 1000nm include:

Country	**LRF Suppliers**
Austria	Riegl Swarovski Optik
Belarus	Pulsar
Canada	Optech Newcon Optik
China	Yiwu TianYing Optical Instrument Co. Jinghua Optical and Electronics Co Hubei Jiuzhiyang Infrared System Co Visionking Optical technology
Finland	Noptel Oy
Germany	Bresser SICK
Japan	Keyence Topcon Nikon
New Zealand	ikeGPS Limited
Singapore	Sintec Optronics
Slovenia	Fotana d.d.
Sweden	Hexagon AB
Switzerland	Vectronix AG Leica Geosystems AG
UK	Spectris

As a meaningful example of the current commercial availability of LRF that would be controlled by the proposed USML Category XII (b)(3) rule, consider the Newcon Optik LRB 20000C. This device employs a 1060nm, q-switched laser. This unit can be purchased from over 500 resellers including:

http://www.bhphotovideo.com

http://www.adorama.com

https://www.outdoorsbay.com

www.ebay.com

www.bonanza.com

www.ramoptic.com

http://www.dhgate.com

www.opt-nightvision.com

http://otomasi.com

http://globalbay.ru

http://www.fixya.com

www.jackscountrystore.co

https://plus.google.com/+Outdoorsbay

http://detail.1688.com/offer/1294934093.html

www.optical-systems.com

It is clear from this single example that restricting US-based companies from competing in the international marketplace through implementation of the proposed rule language of USML Category XII (b)(3) will provide the US government with neither military or intelligence advantage. To the contrary, it will serve to discourage private US investment in the further development of world class LRF technology, endanger public safety and push solutions development for the applications cited above to foreign nations. This condition will inevitably lead the US government to either fund re-development of products already available on the international market or purchase the technology from potential enemies.

Voxtel believes the US Government can achieve critical military and intelligence advantage, preserve current commercial commodity markets and enable critical public safety technology advances by simply adding an upper limit to the laser pulse energy in the proposed USML rule. Voxtel recommends an upper limit of 2mJ. The Voxtel proposed language for CAT XII (b)(3) is:

(3) Laser rangefinders having **both** of the following:

(i) **laser pulse energy exceeding 2mJ**

(ii) Laser output wavelength exceeding 1,000 nm;

Best regards,

George Williams

Attachments:

Appendix A - Commercial LRF Suppliers

Appendix B - Commercial Airborne Scanning LRF Suppliers

Appendix A – Commercial LRF Suppliers






	TY-LR71	JIR-6243/6244	ESLRF	STIR-6243	LRF-3020	LRF MOD 15HF
Laser Pulse Characteristics						
Wavelength [nm]:	1570	1570	1543	1570	1550	1576
Peak Power (kW)		1000		1000		1500
Pulse Energy (mJ)			8			12
Beam divergence [mrad]:		0.8				1.7
Max. pulse frequency [Hz]:	1	10	12	10		5
Accuracy(m)		±1	±2	±1	±3	±1
Max Range (km)	2.5	20	20	20	2	
Temp Range	-40C to 60C	-30C to 60C	-30C to 65C	-30C to 60C	-35C to 55C	
Supplier	Yiwu TianYing Optical Instrument Co. Room 301, 1unit,18Building, Houcheng YiQu, Jiangdong Street Yiwu City,Zhejiang China http://www.nightvisioncn.com	Hubei Jiuzhiyang Infrared System Co. No.16, Wudayuan Road, East Lake Hi-tech District, Wuhan, China www.hbjir.com	Fotana d.d. Stegne 7, 1000 Ljubljana Slovenia www.fotana.si	Sintec Optronics 10 Bukit Batok Crescent #07-02 Singapore 658079 www.sintecoptronics.com	Vectronix Inc. 801 Sycolin Road SE Suite 206 Leesburg, VA 20175 www.vectronix.com	Newcon-Optik 105 Sparks Ave. Toronto, Ontario M2H 2S5 Canada www.newcon-optik.com

Appendix B – Commercial Airborne Scanning LRF Suppliers






	DragonEye400	LiteMapper 5600	ALS70-CM	Optech Orion C ALTM	RIEGL VQ-580	RIEGL LMS-Q780
Laser Pulse Characteristics						
Wavelength [nm]:	1024	1550	1064	1541	1064	1064
Pulse length [ns]:	3	3	4		3	3
Beam divergence [mrad]:	0.5	0.3	0.22	0.25	0.2	0.25
Type/class laser:	Class IV	Class 1	Class IV	Class IV	Class 3B	Class 3B
Eyesafe range [m]:	200		159	7	50	0
Recording Methodology						
Scanning method :	Oblique LiDAR	Rotating multi-facet mirror	Oscillating mirror	Oscillating mirror	Rotating mulit-facet mirror	Rotating mulit-facet mirror
Scan frequency [Hz]:	140		200	90		266000
Min. pulse frequency [Hz]:	50000	240	40	50000	50	100000
Max. pulse frequency [Hz]:	400000	240	500	300000	380	400000
Max. field of view [deg]:	40	60	75	50	60	60
Max. number of recorded echoes per pulse:	Programmable >4 range measurements including last	practically unlimited	practically unlimited	4 discrete; unlimited w/ waveform option	practically unlimited	practically unlimited
Full-wave form digitization:	Y	Y	Y	Y	Y	Y
Pulse sampling frequency [GHz]:	1.8	1	1	1		1
recording of intensity of return signal [bits]:	12		8	12	16	16
Multiple pulses in air:	N	N	Y	Y	Y	Y
Uncertainty and resolution						
Pitch and roll pointing precision [deg]:		0.003	0.005	0.005		0
Heading pointing precision [deg]:		0.007	0.008	0.008		0
Elevation precision at 1 km [m]:	0.005	0.07	0.01	0.02	0.05	0
Planimetric precision at 1km [cm]:	30	0.07	0.12		0.05	0
Across-track point spacing at 1km [m]:		0.85	0.3	0.05	0.8	0.1
Operation Characteristics						
Platform:	Helicopter, Fixed-wing	Helicopter, Fixed-wing	Helicopter, Fixed-wing	Helicopter, Fixed-wing	Helicopter, Fixed-wing	Helicopter, Fixed-wing
Min. flying height [m]:	100	30	200	50	50	0
Max. flying height [m]:	1500	1500	1600	1000	5000	3050
Max. acquisition time [hr]:	8	8	6	30	9	8
Warm-up-time [s]:	120	120	240		60	120
Application						
Main applications:	Urban and rural area surveys, city modelling, infrastructure surveying	Corridor Mapping, City Modelling, Opencast Pits;	Urban mapping, engineering, corridor; etc.	Corridor mapping, engineering, tight-tolerance applications	All typical airborne scanning applications; especially Glacier	All typical airborne scanning applications; Wide Area /

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From:	georgew@voxtel-inc.com
To:	DDTCPublicComments
Subject:	TAR Amendment
Date:	Monday, June 29, 2015 3:59:37 PM
Attachments:	image001.emz image002.png

RE: Public Notice: 22 CFR Part 21 / ITAR Amendment –Category XII /RIN 1400 - AD32

Voxtel is a manufacturer of photoreceivers, ranging instruments, and 3D imaging systems, which we provide to a wide range of developers of industrial and consumer products. A small portion of our sales are also devoted to US military system integrators, who benefit from the economies of scale provided by the commercial marketplace. Our business would not be viable if the amendments are put into effect, as the ratio of commercial to US military demand for our products is greater than 100x.

We believe that while severely flawed, the USML CAT XII be left as is because the proposed amendment of the U.S. Munitions List (USML) Category XII:

(1) Overreaches the stated purpose of the President's Export Control Reform policies by casting a wider net that captures technologies widely available internationally, placing US manufacturers at and economic disadvantage and weakening the US military supply chain, thereby threatening our war fighters;
(2) Places commercial technology already widely available worldwide, in many cases dominated by foreign suppliers, including laser, laser ranging, and laser imaging systems, on the USML,
(3) Places technologies already used by civilian sectors of the US government and State governments, and the data generated, under export controls, thereby creating a compliance burden of significant proportion and cost.
(4) Will significantly increase the cost of components and systems provided to the US military, or likely, will reduce the US supply base by making US suppliers noncompetitive
(5) Includes technologies developed within the commercial markets, in which the ratio of military to commercial sales is several orders of magnitude lower, thereby increasing the cost of technologies for the warfighter and thereby denying them access to technologies, which might provide advantage and save lives.
(6) Places emerging technologies already being used to enhance our nations wellbeing, including: pollution monitoring, corridor and flood plain mapping, automotive safety, turbine monitoring, and many others, under ITAR control, limiting domestic research and development.
(7) Places eyesafe laser technology, required for effective and safe consumer products, under the control of the USML, forcing manufacturers to less eyesafe laser wavelengths.

Table 1 (attached) includes examples of the technologies and components of these technologies, already commercially available.

With specific reference to several of the paragraphs of the proposed the amendment.

Paragraph (b)(2). *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*
It is not obvious that this language is practical or enforceable. There are a wide range of laser diodes and VCSELS that are used in illumination systems for surveillance with silicon cameras. As notes in Table 1, laser diode pointers are available, from both domestic and foreign suppliers, with output from 710 nm out to 1350 nm. Given their widespread use for pumping lasers and in telecommunications, it is not clear that it is possible to restrict these components outside of a system.

Paragraph (b)(3) *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

The wavelength portion of this paragraph cannot be put in force as "the horse is out of the stable." Similarly, the Q-switch cannot be reasonable be controlled, as it too, has been widely available, worldwide, for over a decade.

If the object of the reference to "Q switch" is to restrict pulsed laser light, then it should probably be worded as such. It is possible, for example, to use MOPA or direct modulation to pulse a fiber laser. While Q-switching is one method of pulsing a laser. Also, there is ACTIVE and PASSIVE Q-switching, which need to be differentiated.

As Q-switched laser technology is ubiquitous, in a number of types of systems, throughout the world, and uncontrollable itself. If a company buys a Q-switched laser for use on a rangefinder, does the commodity become controlled. With a $2 Si or InGaAs detector with a 555 timer, both available from Radio Shack, with instructions available in most electrical textbooks and on the web, most high school students can fabricate a rangefinder that meets these categories.

Reflecting, this, as shown in Table 1, there are a large number of commercial suppliers, worldwide, of these components and rangefinders.

The pulse width, pulse jitter, and pulse timing accuracy are more important for the purposes of control, but it is unlikely that a "bright line" can be established separating existing commercial applications.

Possible revisions of this paragraph might be to control the pulse energy of such systems to be, for example, [less than 2 mJ (1550nm) AND a < 10 ns pulse length AND in a system with a beam divergence less than, e.g. 0.5 mRAD]

However, it isn't clear that even this is outside common or widely considered commercial applications.

There are also safety considerations. The proposed rule language would categorically exclude eye-safe laser ranging and imaging devices for consumer purposes. Devices operating below 1000 nm are intrinsically an eye-safety hazard and handicapped in their performance due to the maximum permissible exposure (MPE) to human beings of the emitted laser wavelength. A 1550nm laser rangefinder has a MPE in the joule per square centimeter range. In layman's terms, the 1550nm laser rangefinders are one million times safer for humans than the 9xxnm laser rangefinders. The eyes of infants and young children are especially sensitive to laser emmisions from 9xxnm laser rangefinders. The cornea and eye lenses of young children transmit more radiation back to the retina than for older children and adults. The dilemma presented to active system designers, if the proposed rule language is adopted, will be to trade off range and precision for eye-safety.

Paragraph (b)(4) *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

Note that the following Standards Organizations exist that cover these technologies, and that there is ubiquitous existing 3D mapping acquisition systems and data processing which would be severely restricted by this re-write.

- ASPRS http://redirect.state.sbu/?url=http://www.asprs.org/PPD-Division/Development-of-Guidelines-for-the-Procurement-of-Commercial-Geospatial-Mapping-Products.html
- Open Geospatial Consortium www.opengeospatial.org
- Federal Geographic Data Committee Standards www.fgdc.gov/standards

The requirements of 3D mapping data meeting industry standards governing target location systems or equipment already fielded on UAVs, aircraft and mobile platforms, already exceed the specification of GNSS and guidance paragraph (d) of this category.

Paragraph (b)(6) *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

The technologies of the subchapter are already in widespread use in the LIDAR and LADAR community.

Also, as noted in Table 1, almost all LIDAR and LADAR used in mapping, exceeding the requirements of this paragraph, have lasers operating at 1064 nm, and over the last several years, have migrated to eyesafe lasers at 1550 nm.

The USGS (http://redirect.state.sbu/?url=http://lidar.cr.usgs.gov/) and the NOAA National Geodetic Survey (http://redirect.state.sbu/?url=http://www.ngs.noaa.gov/corbin/class_description/ Lidar_presentations.shtml) has LIDAR data obtained with such systems. They are mostly obtained using services purchased from vendors integrating mostly foreign LIDAR systems (Leica, Optech, etc.) LIDAR instruments, using laser and ranging laser devices with performance controlled by this paragraph.

A list of existing international vendors manufacturing, using, publishing, and consuming data exceeding this specification are at (http://redirect.state.sbu/?url=http://lidar.cr.usgs.gov/knowledge.php)

Paragraph (b)(6)(NOTE 1)
While there is a carve out for automotive applications, there are existing market applications, which in addition to above also include 3D-4D Building Information Modeling, required by the US General Services Administration (http://redirect.state.sbu/?url=http://www.gsa.gov/portal/content/105075), which require EYESAFE ladar with precise geo-referenced data, which require a carve out.

Paragraph (b)(8i)

There are already ubiquitous LIDAR systems or equipment having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft (about 4000 meters), and incorporating or specially designed to incorporate a gimbal mounted transmitter or beam director (see Table 1).

While dependent on optics and scanner control, this specification is largely met by system calibration. Instruments like the Leica ALS70-HP High-Pulse-Rate Airborne LIDAR
Product Specifications (http://redirect.state.sbu/?url=http://www.leica-geosystems.com/en/Leica-ALS70-Airborne-Laser-Scanner_94516.htm) readily achieve this accuracy, but this specification is only relevant for a LIDAR system mounted on an airborne platform and should be restricted as such.

Paragraph (b)(8ii) *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

Most of the commercial systems listed in Table 1 use > 1000 nm lasers and have the capability to detect 10 mm wire at 500 m. In fact, most of the airborne systems listed in Table 1 (paragraph b8) are specified to meet this specification at ranges of several kilometers. Modeling will show that a simple pulsed 1064 nm laser diode or fiber laser, with narrow FOV optic can readily detect wire at 500 m.

It would make sense to control this technology only when coupled to a navigation or guidance system.

Paragraph (b)(8ii) *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

Even for the designer, it is very difficult to know the electrical bandwidth of a detector readout. Bandwidth is difficult to measure. Also the gain-bandwidth product is more important than bandwidth, and even so, it is not clear what this paragraph is trying to control. It seems to want to control a timing resolution.

It is important to note that while the bandwidth is relevant for pulse pair resolution of a receiver, it is possible to get fine resolution with a < 100 MHz bandwidth detector. In fact, as noise is dependent on bandwidth, often a < 100 Mhz bandwidth detector has better time resolution than, e.g. > 1 GHz bandwidth receiver.

If it is timing that is of concern, this paragraph needs to be rewritten to better reflect timing jitter (e.g. < 200 ps)

Also, while a Geiger-mode detector array is by definition sensitive to a single photon, a linear mode detector is not and may have any sensitivity from a single photon to many hundreds or thousands of photons. This range of performance should not be governed by a single level of control.
Thus, it seems reasonable to specify an array size only with respect to performance, and then it should include levels of control for embedded FPAs, modules, embedded systems, etc, such as are proposed for the passive IRFPAs.

Paragraph e4. *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

This control is problematic for a number of reasons. First, it controls the ROICS more stringently than the IRFPAS they are integrated into.

BY controlling ROIC wafers they are controlled at the semiconductor fab, restricting US companies from using the state of the art (e.g. sub-64-nm) semiconductor processes available worldwide. Similarly 3D wafer stacking and other advanced processing and packaging services are not available domestically or are not available on an ITAR process flow.

There remain only a few domestic semiconductor fabs and it is not clear if more than one is qualified for ITAR controlled wafer processing. IBM was recently sold to global foundries. Jazz is foreign owned, and only recently accommodates an ITAR controlled process flow, and ON Semiconductor.

For this reason, this paragraph, as written, would put the US military at a severe disadvantage. Most of the imaging market is dominated by foreign companies, and this would further push leadership of imaging technologies to foreign suppliers.

***(f) Technical data** *We recommend that this language be not adopted and be stricken from the CAT XII amendments as it encompasses commercial technology that is in widespread use internationally, and its enforcement would jeopardize the private investment by US industry, reduce the competitiveness of the US supply base by restricting the markets and economies of scale of the commercial marketplace available to US suppliers, and thereby will put our warfighters at risk.*

Software and technical data include that include design or manufacturing process descriptions (e.g., steps, sequences, conditions, parameters) for lasers described in paragraphs (b)(6) and (b)(9), would require that a vast amount of existing data be re-classified and companies that are currently not ITAR compliant put in place ITAR compliant systems, which would require re-staffing. The costs are immeasurable.

Structures for ROICs controlled in paragraph (e)(4) or (5) of this category, and specially designed ROICs controlled in paragraphs (e)(4) and (5) of this category (including bonding or mating (e.g., hybridization of IRFPA, again would place the most advanced bonding and processing technologies out of the hands of US suppliers. This regulation would cripple the performance of US produced IRFPAs and active imagers.

OTHER CONSIDERATIONS

There are a wide number of important technologies which rely on the items proposed for control, which would be surrendered to foreign developers. Placing the technologies on the USML would limit development of a vast array of technologies important for the quality of life and safety of US citizens and is important for US economic growth. Examples of important research put in jeopardy by these regulations include:

Eye-Safe Lidar System for Pesticide Spray Drift
Measurement
Gregorio, E.; Rocadenbosch, F.; Sanz, R.; Rosell-Polo, J.R.
Eye-Safe Lidar System for Pesticide Spray Drift Measurement. *Sensors* 2015, *15*, 3650-3670. (SPAIN)
http://redirect.state.sbu/?url=http://www.mdpi.com/1424-8220/15/2/3650
The instrument is based on a 3-mJ pulse-energy erbium-doped glass laser, an 80-mm diameter telescope, an APD optoelectronic receiver and optomechanically adjustable components. In first test measurements, the LIDAR system has been able to measure a topographic target located over 2 km away. The instrument has also been used in spray drift studies, demonstrating its capability to monitor the temporal and distance evolution of several pesticide clouds emitted by air-assisted sprayers at distances between 50 and 100 m.

Eye-safe aerosol LIDAR at 1.5 microns: progress towards a scanning LIDAR network
Scott M. Spuler and Shane D. Mayor

phys.csuchico.edu/~sdmayor/conf_papers/Spuler_Mayor_SPIE07.pdf

A multi-dimensional scanning lidar has been developed for tracking and monitoring aerosol plumes in urban settings. The reliability of the system has been demonstrated and plans for additional units are in place to create a unique scanning lidar network. The paper discusses the current capabilities of the instrument and research underway to extract more information, such as quantitative aerosol properties, from the network.

MOBILE LIDAR: THE BENEFITS TO AIRPORTS FROM AN OPERATIONS AND SAFETY PERSPECTIVE

www.airporttech.tc.faa.gov/

In 2007, the Federal Aviation Administration (FAA) approved the use of airborne lidar (light detection and ranging) in conjunction with aerial imagery that is collected concurrently to perform obstruction surveys following FAR Part 77.

http://redirect.state.sbu/?url=http://www.masterbuilder.co.in/application-of-lidar-in-surveying-and-civil-engineering/

TABLE 1: PROPOSED CHANGS TO CAT 12 and EXAMPLES OF COMMERCIAL AND FOREIGN SUPPLIER COMPONENTS ON MARKET

22 CFR Part 121 Paragraph	Technology	Existing Commercially Available Product	Web Site
(b.3.i) Lasers, and laser systems and equipment, as follows: 3) Laser rangefinders having any of the following: (i) Q-switched laser pulse; or (ii) Laser output wavelength exceeding 1,000 nm;	Q-switched and 1064 nm or 1550 nm laser technology	Photop Technologies, Inc (CHINA)	http://redirect.state.sbu/?url=http://www.photoptech.com/main/products_jg/q_switched2.php
		TEEM Photonics (France)	http://redirect.state.sbu/?url=http://www.teemphotonics.com/products.html/infrared-lasers.html
		V-GEN (Israel)	http://redirect.state.sbu/?url=http://www.spectra-physics.com/products/fiber-lasers
		Crystaltechno Ltd (Russia)	www.crystaltechno.com - 1576 nm
		Vextronix (SWISS) VECTOR 21 AERO – 1540 nm, 12 km range - 360° digital compass	http://redirect.state.sbu/?url=http://www.vectronix.ch/html/en/products/handheld_equipment/rangefinders/vector_rangefinder_binoculars/vector_21_aero_the_law_enforcement_device
		Yiwu Tianying Optical Instrument Co., (CHINA) Limited 20km 0.2Hz Continuous Rate Military Eye Safe Laser Rangefinder Binoculars	http://redirect.state.sbu/?url=http://www.made-in-china.com/showroom/hawksoptic/product-detaildbkQsaVKCYWn/China-20km-0-2Hz-Continuous-Rate-Military-Eye-Safe-Laser-Rangefinder-Binoculars.html (1064 nm)
		EOS Optronics GmbH - (Germany) ELRF Eye Safe Laser Range Finder 1.54 µm - 50 – 10000 m	www.eos-aus.com
		Keopsys (France)	http://redirect.state.sbu/?url=http://www.keopsys.com/index.php/en/products-n-services/pulsed-laser/pefl.html
		Jenoptic – 10 km, 1554 nm	http://redirect.state.sbu/?url=http://www.jenoptik.com/en_50427_elem-dp_10k
		Also see Table 2	
(b2) Lasers, with a laser output exceeding 710 nm	Laser illuminators with greater than 710 nm	Electrophysics 808-nm-emitting laser diode integrated with a thin-sheet optic and holographic diffuser.	www.electrophysics.com/.../WP-App%20Analysis%20of%20Near-IR%2.
		Laser Pointers - Available in three infrared light frequencies of 808nm, 980nm, 1064nm, as well as 1342. Includes FDA approval, air cooling, high stability and efficiency diode, backed warranty, and a long expected life time. - See more at: http://redirect.state.sbu/?url=http://www.biglasers.com/infrared-laser-pointer#sthash.EOHXku8H.dpuf	"IR1" Laser Pointer 808nm - 980nm - 1064nm - 1342nm - See more at: http://redirect.state.sbu/?url=http://www.biglasers.com/infrared-laser-ointer#sthash.EOHXku8H.dpuf
		Hamamatsu - High-power Laser Diode Bar Module	http://redirect.state.sbu/?url=http://www.hamamatsu.com/jp/en/L8413-50-808.html
		Youtube	http://redirect.state.sbu/?url=https://www.youtube.com/watch?v=hhHhdnEis1k
		JDSU	http://redirect.state.sbu/?url=http://www.jdsu.com/en-us/Lasers/Products/diode-lasers/Pages/default.aspx#.VUql5ZOYEU0
		Excelitas (Canada)	http://redirect.state.sbu/?url=http://www.excelitas.com/Pages/Product/Pulsed-Laser-Diodes-for-Near-Infrared-NIR-750-nm-950-nm.aspx
B4. (4) Targeting or target location systems or equipment incorporating or specially designed to incorporate a laser rangefinder controlled in paragraph (b)(3) of this category, and incorporating or specially designed to incorporate a Global Navigation Satellite System (GNSS), guidance or navigation article controlled in paragraph (d) Guidance or navigation systems (e.g., inertial navigation systems, inertial measurement units, inertial reference units, attitude and heading reference Having a circle of equal probability (CEP) of position error rate less (better) than 0.35 nautical miles per hour; systems) as follows Having a heading error or true north	Rangefinders with GNSS	Trimble ax60 airborne lidar – 4700 m, 2 cm accuracy, < 20 cm 9.25 mrad beam divergence - Trimble AP50 GNSS/IMU	http://redirect.state.sbu/?url=http://www.trimble.com/Imaging/AX60.aspx

determination of less (better) than 0.50 mrad secant (latitude) (0.02865 degrees secant (latitude)); or (iii) Specified to function at linear acceleration levels exceeding 25 g;			
(b6) Light detection and ranging (LIDAR), laser detection and ranging (LADAR), or range-gated systems or equipment, incorporating or specially designed to incorporate an article controlled in this subchapter Note to paragraph (b)(6): This paragraph does not control LIDAR systems or equipment for civil automotive applications having a range limited to 200 m or less.	LIDAR, except auto less than 200 m	Optech ILRIS Terrestrial Laser Scanner range capability (exceeds 3000 meters)	http://redirect.state.sbu/?url=http://www.optech.com/index.php/product/optech-ilris/
		Topcon GLS-1500 – ranging past 330 meters; 3" at 50m	http://redirect.state.sbu/?url=https://www.topconpositioning.com/mass-data-collection/laser-scanners/gls-2000
(b8i) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows Systems or equipment having a resolution (i.e., ground point spacing) of 0.2 m or less (better) from an altitude above ground level of greater than 16,500 ft, and incorporating or specially designed to incorporate a gimbal mounted transmitter or beam director, and specially designed parts and components therefor;	LIDAR with ground 0.2 m res at 16, 500 ft (app. 4000 m)	Optech Orion C300-1: 1/7500 x altitude; 5 mm (z); 1541 nm; Across-track point spacing at 1km [m]: 0.05	
		RIEGL VZ-4000 This 3D VZ-Line Laser Scanner offers superior and unrivalled long range measurement performance of up to 4000 m reflectorlessly with 1while still maintaining completely eye safe operation (Laser Class 1). RIEGL's unique V-Line technology is based on echo digitization and online waveform processing and is the key to enabling such extreme long range measurements.	http://redirect.state.sbu/?url=http://www.mena3d.com/lidar-technology.html
(b8ii) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows(ii) Aircraft systems or equipment having a laser output wavelength exceeding 1,000 nm and a detection range exceeding 500 m for an obstacle with a diameter or width less than or equal to 10 mm (e.g., wire, power line);	LIDAR with > 1000 nm laser and > 500 m range for 10 mm wire	Leica ALS80-CM and Leica ALS80-HP provide 1 cm accuracy at 500 m, more than sufficient for wire	http://redirect.state.sbu/?url=http://www.leica-geosystems.us/en/Airborne-Imaging_86816.htm
		Riegle VUX-1 UAV LIDAR – capable of wire at 500 m	http://redirect.state.sbu/?url=http://products.rieglusa.com/product/airborne-scanners/nners-vux-1-ultra-lighweight-uas-uav-laser-scanner
(b8 iii) LIDAR, LADAR, or other laser range-gated systems or equipment, as follows (iii) Systems or equipment having an electrical bandwidth of 100 MHz or greater, and incorporating or specially designed to incorporate either a Geiger-mode detector array having at least 32 elements or a linear-mode detector array having at least 128 elements;	LIDAR with > 100 MHz BW	Aurea Technology (France)	http://redirect.state.sbu/?url=http://aureatechnology.net/en/applications/lidar.html
C2 (2) Photon detector, microbolometer detector, or multispectral detector infrared focal plane arrays (IRFPAs) having a peak response within the wavelength range exceeding 900 nm but not exceeding 30,000 nm and not integrated into a permanent encapsulated sensor assembly, and detector elements therefor;	IR focal planes	Hamamatsu InGaAs area image sensor 64 x 64 model G11097-0606S	http://redirect.state.sbu/?url=http://www.hamamatsu.com/jp/en/G11097-0606S.html
C4 Two-dimensional photon detector IRFPAs described in paragraph (c)(2) of this category in a permanent encapsulated sensor assembly, having greater than 256 detector elements		Atik Cameras (UK) - 16MPixel Short Wave Infra-Red scanning camera featuring an InGaAs sensor for imaging in the 0.9um to 1.7um range	http://redirect.state.sbu/?url=http://www.atik-cameras.com/where-to-buy-atik-cameras/
		Mikro Tassim 640 x 512	http://redirect.state.sbu/?url=http://www.mikro-tasarim.com.tr/products/view/5

		Stemmer Imaging (UK)	www.stemmer-imaging.co.uk/
Category VIII. (3) Wafers incorporating structures for either a ROIC controlled in paragraph (e)(4) or (5) of this category, or an IRFPA or detector elements therefor controlled in paragraph (c)(2) of this category; - (ii) Two-dimensional photon detector IRFPA having greater than 256 detector elements; (4) (4) Read-Out Integrated Circuits (ROICs) specially designed for an IRFPA controlled in paragraph (c)(2) of this category or detector elements therefor, as follows: (ii) Two-dimensional photon detector IRFPA having greater than 256 detector elements (16 x 16); Note to paragraph (5) ROICs specially designed for a camera/core/packaged IRFPA subject to the controls of this subchapter; (e)(4): ROICs are specially designed for an infrared focal plane array detector even if the detector is incorporated into an item that is not enumerated on the U.S. Munitions List.	ROICS – seemingly all ROICs if they are IR	Mikro-Tasarim (Turkey) ROIC	http://redirect.state.sbu/?url=http://www.mikro-tasarim.com.tr/
Note 2 to paragraph (c): The articles described in paragraphs (c)(1) through (5), (c)(7), (c)(8), and (c)(12) other than (c)(12)(ix) having greater than 640 detector elements in any dimension, and (c)(12)(x) are subject to the EAR when, prior to export, reexport, retransfer, or temporary import, they are integrated into and included as an integral part of an item subject to the			

LIDAR Mapping

http://redirect.state.sbu/?url=http://lidar.cr.usgs.gov/knowledge.php

Table 2 – Commercial 1000-1700 nm LRF Suppliers

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International Traffic in Arms: U.S. Munitions List Category XII; Revision

Comment On: DOS-2015-0027-0001
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Comment on DOS_FRDOC_0001-3226

Submitter Information

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Submitter's Representative: Louise Slaughter
Organization: Univ. of Rochester
Government Agency Type: Federal
Government Agency: NASA

General Comment

The current state of ITAR regulations is detrimental to the progress of Astronomy, which is my profession. We work with Aerospace companies, such as Teledyne and Raytheon, to develop infrared sensitive detector arrays for Space Astronomy. Our research is funded by NASA. The arrays are produced by the Aerospace company in consultation with the astronomers at the Univ. of Rochester. Certainly, similar devices are used by the Armed Forces, but the devices we are developing are not appropriate for Strategic applications. The infrared background in a well designed space observatory is approximately one million times lower than found in strategic applications. This dictates quite different construction techniques, to achieve the very low dark currents required for space. Furthermore, the power dissipation requirements for a space observatory are very low, circa 1 mW per megapixel.

Thus our technology development is only peripherally related to arms development. At the same time, the ITAR regulations are very onerous to my institution, the Univ. of Rochester. On many research projects in the recent past, we have had considerable difficulty getting our administration to approve of our research because of these ITAR implications. At the same time, Aerospace companies in Europe are developing similar technology, and they advertise their products as 'ITAR free'. This puts our native manufacturers at a distinct disadvantage. We are at risk of losing the competitive advantage our companies have in this field currently.

Therefore I request that the ITAR regulations covering infrared arrays for space astronomy be loosened, consistent with the real lack of threat this technology poses to US interests, and pursuant to promoting the leading Aerospace companies working in this area and the progress of Astronomy.

UNIVERSITY OF CALIFORNIA, BERKELEY

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Department of State
2401 E Street NW, SA-1, Room H1200
Washington, DC 20037

Subject: Amendment to the International Traffic in Arms Regulations: Revision of U.S. Munitions List Category XII

To Whom It May Concern:

My name is Xiang Zhang. I am the Ernest S. Kuh Endowed Chair Professor at University of California, Berkeley and the Materials Sciences Division Director at Lawrence Berkeley National Laboratory. My research mainly involves micro-nano scale engineering, novel 3D fabrication technologies in microelectronics and photonics, micro and nano-devices, nano-lithography and nano-instrumentation, rapid prototyping, bio-MEMS, and semiconductor manufacturing.

I， Xiang Zhang at University of California, Berkeley, appreciates the opportunity to comment on the proposed changes to the EAR.

My lab at 5130 Etcheverry Hall, University of California, Berkeley conduct research involving nano-optical charactorizations, optical imaging, and optoelectronic experiments. We routinely use and will use EMCCDs, intensifier CCDs, and near-infrared InGaAs Cameras. My lab would be unable to purchase or use any ITAR controlled equipment. As a whole, University of California at Berkeley is very hesitant to purchase any ITAR restricted items as restricting their access to foreign graduate students is onerous. As a Principal Investigator, it would be impossible for me to justify the purchase of a scientific tool that could not be used by many of my students.

It would be especially devastating for the photonics research community if the US government were to place ITAR restrictions on scientific grade cameras, such as intensifier CCD, near infrared InGaAs and EMCCD cameras. If this were to happen, it will setback US research significantly, especially, in contrast to the research in EU and Asia have no such restrictions exist from their respective Governments.

I feel the proposed changes would present a major restriction of basic photonics research and therefore I would not support it.

If you require any further information, please contact me at 510-643-4978 or via email at xiang@berkeley.edu

Sincerely,

Xiang Zhang, Ph. D
Ernest S. Kuh Endowed Chair and Director
University of California, Berkeley