AIR FORCE
15.A SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)
PROPOSAL PREPARATION INSTRUCTIONS

Revised Closing Date: February 25, 2015, at 6:00 a.m. ET

The Air Force (AF) proposal submission instructions are intended to clarify the Department of Defense (DoD) instructions as they apply to AF requirements.

The Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio, is responsible for the implementation and management of the AF Small Business Innovation Research (SBIR) Program/Small Business Technology Transfer (STTR) Program.

The AF Program Manager is Mr. David Sikora, 1-800-222-0336. For general inquiries or problems with the electronic submission, contact the DoD SBIR/STTR Help Desk at [1-800-348-0787] or Help Desk email at [sbirhelp@bytecubed.com] (8:00 a.m. to 5:00 p.m. ET Monday through Friday). For technical questions about the topics during the pre-solicitation period (12 December 2014 through 14 January 2015), contact the Topic Authors listed for each topic on the Web site. For information on obtaining answers to your technical questions during the formal solicitation period (15 January through 25 February 2015), go to http://www.dodsbir.net/sitis/.

General information related to the AF Small Business Technology Transfer Program can be found at the AF Small Business website, http://www.airforcesmallbiz.org. The site contains information related to contracting opportunities within the AF, as well as business information, and upcoming outreach/conference events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers, http://www.aptac-us.org. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

The AF STTR Program is a mission-oriented program that integrates the needs and requirements of the AF through R&D topics that have military and/or commercial potential.

Efforts under the STTR program fall within the scope of fundamental research. The Under Secretary of Defense (Acquisition, Technology, & Logistics) defines fundamental research as "basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community," which is distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons. See DFARS 252.227-7018 for a description of your SBIR/STTR rights.

PHASE I PROPOSAL SUBMISSION

Read the DoD program solicitation at www.dodsbir.net/solicitation for program requirements. When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. For the AF, the contract period of performance for Phase I shall be nine (9) months, and the award shall not exceed $150,000. We will accept only one Cost Volume per Topic Proposal and it must address the entire nine-month contract period of performance.

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each AF organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and review by the AF technical point of contact utilizing the criteria in section 6.0 of the DoD solicitation. The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners (see "Phase II Proposal Submissions" below); no modification to the Phase I contract should be necessary.

The Phase I Technical Volume has a 20-page limit (excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), Company Commercialization Report and NDA Requirement Form.

Limitations on Length of Proposal

The Technical Volume must be no more than 20 pages (no type smaller than 10-point on standard 8-1/2" x 11" paper with one (1) inch margins). The Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), and Company Commercialization Report are excluded from the 20-page limit. Only the Technical Volume and any enclosures or attachments count toward the 20-page limit. In the interest of equity, pages in excess of the 20-page limitation (including attachments, appendices, or references, but excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), and Company Commercialization Report), will not be considered for review or award.

Phase I Proposal Format

Proposal Cover Sheet: The Cover Sheet does NOT count toward the 20-page total limit. If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet. Therefore, DO NOT include proprietary information in these sections.

Technical Volume: The Technical Volume should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Topic Proposal. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your uploaded file will be virus checked and converted to a .pdf document within the hour. However, if your proposal does not appear after an hour, please contact the DoD SBIR/STTR Help Desk at [1-800-348-0787] or Help Desk email at [sbirhelp@bytecubed.com] (8:00 am to 5:00 pm ET).

Key Personnel: Identify in the Technical Volume all key personnel who will be involved in this project; include information on directly related education, experience, and citizenship. A technical resume of the principle investigator, including a list of publications, if any, must be part of that information. Concise technical resumes for subcontractors and consultants, if any, are also useful. You must identify all U.S. permanent residents to be involved in the project as direct employees, subcontractors, or consultants. You must also identify all non-U.S. citizens expected to be involved in the project as direct employees, subcontractors, or consultants. For all non-U.S. citizens, in addition to technical resumes, please provide countries of origin, the type of visa or work permit under which they are performing and an explanation of their anticipated level of involvement on this project, as appropriate. You may be asked to provide additional information during negotiations in order to verify the foreign citizen's eligibility to participate on a contract issued as a result of this solicitation.

Voluntary Protection Program (VPP): VPP promotes effective worksite-based safety and health. In the VPP, management, labor, and the Occupational Safety and Health Agency (OSHA) establish cooperative relationships at workplaces that have implemented a comprehensive safety and health management system. Approval into the VPP is OSHA's official recognition of the outstanding efforts of employers and employees who have achieved exemplary occupational safety and health. An "Applicable

Contractor" under the VPP is defined as a construction or services contractor with employees working at least 1,000 hours at the site in any calendar quarter within the last 12 months that is NOT directly supervised by the applicant (installation). The definition flows down to affected subcontractors. Applicable contractors will be required to submit Days Away, Restricted, and Transfer (DART) and Total Case Incident (TCIR) rates for the past three years as part of the proposal. Pages associated with this information will NOT contribute to the overall technical proposal page count. NOTE: If award of your firm's proposal does NOT create a situation wherein performance on one Government installation will exceed 1,000 hours in one calendar quarter, **SUBMISSION OF TCIR/DART DATA IS NOT REQUIRED**.

Phase I Work Plan Outline

NOTE: THE AF USES THE WORK PLAN OUTLINE AS THE INITIAL DRAFT OF THE PHASE I STATEMENT OF WORK (SOW). THEREFORE, DO NOT INCLUDE PROPRIETARY INFORMATION IN THE WORK PLAN OUTLINE. TO DO SO WILL NECESSITATE A REQUEST FOR REVISION AND MAY DELAY CONTRACT AWARD.

At the beginning of your proposal work plan section, include an outline of the work plan in the following format:

1) Scope: List the major requirements and specifications of the effort.
2) Task Outline: Provide a brief outline of the work to be accomplished over the span of the Phase I effort.
3) Milestone Schedule
4) Deliverables
    a. Kickoff meeting within 30 days of contract start
    b. Progress reports
    c. Technical review within 6 months
    d. Final report with SF 298

Cost Volume

Cost Volume information should be provided by completing the on-line Cost Volume form and including the Cost Volume Itemized Listing (a-j) specified below. The Cost Volume information must be at a level of detail that would enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a-j below) on how funds will be used if the contract is awarded. The on-line Cost Volume and Itemized Cost Volume Information (a-j) will not count against the 20-page limit. The itemized listing may be placed in the "Explanatory Material" section of the on-line Cost Volume form (if enough room), or as the last page(s) of the Technical Volume Upload. (Note: Only one file can be uploaded to the DoD Submission Site). Ensure that this file includes your complete Technical Volume and the Cost Volume Itemized Listing (a-j) information.

a. Special Tooling and Test Equipment and Material: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness of the work proposed. The purchase of special tooling and test equipment must, in the opinion of the Contracting Officer, be advantageous to the government and relate directly to the specific effort. They may include such items as innovative instrumentation and/or automatic test equipment.

b. Materials: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, and price and where appropriate, purposes.

c. Other Direct Costs: This category of costs includes specialized services such as machining or milling, special testing or analysis, costs incurred in obtaining temporary use of specialized equipment. Proposals which include leased hardware, must provide an adequate lease vs. purchase justification or rational.

d. Direct Labor: Identify key personnel by name if possible or by labor category if specific names are not available. The number of hours, labor overhead and/or fringe benefits and actual hourly rates for each individual are also necessary.

e. Travel: Travel costs must relate to the needs of the project. Break out travel cost by trip, with the number of travelers, airfare, per diem, lodging, etc. The number of trips required, as well as the destination and purpose of each trip should be reflected. Recommend budgeting at least one (1) trip to the Air Force location managing the contract.

f. Cost Sharing: Cost sharing is permitted. However, cost sharing is not required nor will it be an evaluation factor in the consideration of a proposal. Please note cost share contracts or portions of contracts do not allow fee. NOTE: Subcontract arrangements involving provision of Independent Research and Development (IR&D) support are prohibited in accordance with Under Secretary of Defense (USD) memorandum "Contractor Cost Share", dated 16 May 2001, as implemented by SAF/AQ memorandum, same title, dated 11 Jul 2001.

g. Subcontracts: Involvement of a research institution is required in the project. Involvement of other subcontractors or consultants may also be desired. Describe in detail the tasks to be performed in the Technical Volume and include information in the Cost Volume for the research institution and any other subcontractors/consultants. The proposed total of all consultant fees, facility leases or usage fees, and other subcontract or purchase agreements may not exceed 60 percent of the total contract price or cost, unless otherwise approved in writing by the Contracting Officer. The STTR offeror's involvement must equate to not less than 40 percent of the overall effort and the research institutions must equate to not less than 30 percent.

Support subcontract costs with copies of the subcontract agreements. The supporting agreement documents must adequately describe the work to be performed, i.e., Cost Volume. At a minimum, an offeror must include a Statement of Work (SOW) with a corresponding detailed cost proposal for each planned subcontract.

h. Consultants: Provide a separate agreement letter for each consultant. The letter should briefly state what service or assistance will be provided, the number of hours required, and hourly rate.

i. Any exceptions to the model Phase I purchase order (P.O.) found at https://www.afsbirsttr.com/Proposals/Default.aspx (see "NOTE" below)

NOTE: If no exceptions are taken to an offeror's proposal, the Government may award a contract without discussions (except clarifications as described in FAR 15.306(a)). Therefore, the offeror's initial proposal should contain the offeror's best terms from a cost or price and technical standpoint. In addition, please review the model Phase I P.O. found at https://www.afsbirsttr.com/Proposals/Default.aspx and provide any exception to the clauses found therein with your cost proposal. Full text for the clauses included in the P.O. may be found at http://farsite.hill.af.mil. Please note, the posted P.O. template is for the Small Business Innovation Research (SBIR) Program. While P.O.s for STTR awards are very similar, if selected for award, **the contract or P.O. document received by your firm may vary in format/content. If there are questions regarding the award document, contact the Phase I Contracting Officer listed on the selection notification.** (See item g under the "Cost Volume" section, p. AF-4.) The Government reserves the right to conduct discussions if the Contracting Officer later determines them to be necessary.

j. DD Form 2345: For proposals submitted under export-controlled topics (either International Traffic in Arms (ITAR) or Export Administration Regulations (EAR)), a copy of the certified DD Form 2345, Militarily Critical Technical Data Agreement, or evidence of application submission must be included. The form, instructions, and FAQs may be found at the United States/Canada Joint Certification Program website, http://www.dlis.dla.mil/jcp/. Approval of the DD Form 2345 will be verified if proposal is chosen for award.

NOTE: Only Government employees may evaluate proposals. AF support contractors may be used to administratively or technically support the Government's STTR Program execution. DFARS 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends (Mar 2011), allows Government support contractors to do so without company-to-company NDAs only AFTER the support contractor notifies the STTR firm of its access to the STTR data AND the STTR firm agrees in writing no NDA is necessary. If the STTR firm does not agree, a company-to-company NDA is required. The attached "NDA Requirements Form" (page 9) must be completed, signed, and included in the Phase I proposal, indicating your firm's determination regarding company-to-company NDAs for access to STTR data by AF support contractors. This form will not count against the 20-page limitation.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Failure to meet any of the criteria will result in your proposal being **REJECTED** and the Air Force will not evaluate your proposal.

1) The Air Force Phase I proposal shall be a nine-month effort and the cost shall not exceed $150,000.

2) The Air Force will accept only those proposals submitted electronically via the DoD SBIR Web site (www.dodsbir.net/submission).

3) You must submit your Company Commercialization Report electronically via the DoD SBIR website (www.dodsbir.net/submission).

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR website at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the Web site. Your complete proposal **must** be submitted via the submissions site on or before the **6:00 am ET, 25 February 2015 deadline.** A hardcopy **will not** be accepted.

> The AF recommends that you complete your submission early, as computer traffic gets heavy near solicitation close and could slow down the system. **Do not wait until the last minute.** The AF will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please ensure your e-mail address listed in your proposal is current and accurate. By late February, you will receive an e-mail serving as our acknowledgement we have received your proposal. **The AF is not responsible for ensuring notifications are received by firms changing mailing address/e-mail address/company points of contact after proposal submission without proper notification to the AF. Changes of this nature that occur after proposal submission or award (if selected) for Phase I and II shall be sent to the Air Force SBIR/STTR site address, afprogram@afsbirsttr.net**

AIR FORCE SBIR/STTR SITE

As a means of drawing greater attention to SBIR/STTR accomplishments, the AF has developed a SBIR/STTR site at http://www.afsbirsttr.com. Along with being an information resource concerning SBIR policies and procedures, the SBIR/STTR site is designed to help facilitate the Phase III transition process. To this end, the SBIR/STTR site contains SBIR/STTR Success Stories written by the Air Force and Phase II summary reports written and submitted by SBIR/STTR companies. Since summary reports are intended for public viewing via the Internet, they should not contain classified, sensitive, or proprietary information.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in section 6.0 of the DoD solicitation in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), and followed by Commercialization Plan. The AF will utilize Phase II evaluation criteria in section 8.0 of the DoD solicitation; however, the order of importance will differ. The AF will evaluate proposals in descending order of importance with technical merit being most important, followed by the Commercialization Plan, and then qualifications of the principal investigator (and team). Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the Government will be considered in determining the successful offeror. The next tie-breaker on essentially equal proposals will be the inclusion of manufacturing technology considerations.

The proposer's record of commercializing its prior SBIR and STTR projects, as shown in its Company Commercialization Report, will be used as a portion of the Commercialization Plan evaluation. If the "Commercialization Achievement Index (CAI)", shown on the first page of the report, is at the 20th percentile or below, the proposer will receive no more than half of the evaluation points available under evaluation criterion (c) in Section 6 of the DoD 14.A STTR instructions. This information supersedes Paragraph 4, Section 5.4e, of the DoD 14.A STTR instructions.

A Company Commercialization Report showing the proposing firm has no prior Phase II awards will not affect the firm's ability to win an award. Such a firm's proposal will be evaluated for commercial potential based on its commercialization strategy.

Online Proposal Status and Debriefings

The AF has implemented on-line proposal status updates for small businesses submitting proposals against AF topics. At the close of the Phase I Solicitation – and following the submission of a Phase II via the DoD SBIR/STTR Submission site (https://www.dodsbir.net/submission) – small business can track the progress of their proposal submission by logging into the Small Business Area of the AF SBIR/STTR site (http://www.afsbirsttr.com). The Small Business Area (http://www.afsbirsttr.com/Firm/login.aspx) is password protected and firms can view their information only.

To receive a status update of a proposal submission, click the “Proposal Status” link at the top of the page in the Small Business Area (after logging in). A listing of proposal submissions to the AF within the last 12 months is displayed. Status update intervals are: Proposal Received, Evaluation Started, Evaluation Completed, Selection Started, and Selection Completed. A date will be displayed in the appropriate column indicating when this stage has been completed. If no date is present, the proposal submission has not completed this stage. Small businesses are encouraged to check this site often as it is updated in real-time and provides the most up-to-date information available for all proposal submissions**. Once the “Selection Completed” date is visible, it could still be a few weeks (or more) before you are**

contacted by the AF with a notification of selection or non-selection. The AF receives thousands of proposals during each solicitation. The notification process requires specific steps to be completed prior to a Contracting Officer approving and distributing this information to small businesses.

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Cover Sheet will be notified by e-mail regarding proposal selection or non-selection. The email will include a link to a secure Internet page containing specific selection/non-selection information. Small businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced. **Again, if changes occur to the company mail or email address(es) or company points of contact after proposal submission, the information shall be provided to the AF at afprogram@afsbirsttr.net.**

A debriefing may be received by written request. As is consistent with the DoD SBIR/STTR solicitation, the request must be received within 30 days after receipt of notification of non-selection. Written requests for debrief must be uploaded to the Small Business Area of the AF SBIR/STTR site (http://www.afsbirsttr.com). Requests for debrief should include the company name and the telephone number/e-mail address for a specific point of contract, as well as an alternate. Also include the topic number under which the proposal(s) was submitted, and the proposal number(s). Further instructions regarding debrief request preparation/submission will be provided within the Small Business Area of the AF SBIR/STTR site. Debrief requests received more than 30 days after receipt of notification of non-selection will be fulfilled at the Contracting Officers' discretion. Unsuccessful offerors are entitled to no more than one debriefing for each proposal.

IMPORTANT: Proposals submitted to the AF are received and evaluated by different offices within the Air Force and handled on a Topic-by-Topic basis. Each office operates within their own schedule for proposal evaluation and selection**. Updates and notification timeframes will vary by office and Topic. If your company is contacted regarding a proposal submission, it is not necessary to contact the AF to inquire about additional submissions.** Check the Small Business Area of the AF SBIR/STTR site for a current update. Additional notifications regarding your other submissions will be forthcoming.

We anticipate having all the proposals evaluated and our Phase I contract decisions within approximately three months of proposal receipt. **All questions concerning the status of a proposal or debriefing should be directed to the local awarding organization SBIR/STTR Program Manager.**

PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology found feasible in Phase I. Only Phase I awardees are eligible to submit a Phase II proposal. All Phase I awardees will be sent a notification with the Phase II proposal submittal date and a link to detailed Phase II proposal preparation instructions. If the mail or email address(es) or firm points of contact have changed since submission of the Phase I proposal, correct information shall be sent to the AF at afprogram@afsbirsttr.net. Phase II efforts are typically two (2) years in duration with an initial value not to exceed $750,000.

NOTE: All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system. It is strongly urged that an approved accounting system be in place prior to the AF Phase II award timeframe. If you do not have a DCAA approved accounting system, this will delay/prevent Phase II contract award. If you have questions regarding this matter, please discuss with your Phase I Contracting Officer.

All proposals must be submitted electronically at www.dodsbir.net/submission. The complete Topic Proposal - Department of Defense (DoD) Cover Sheet, Itemized Cost Volume information, entire Technical Volume with appendices, Cost Volume and the Company Commercialization Report – must be submitted by the date indicated in the notification. The technical proposal is **limited to 50 pages** (unless a different number is specified in the preparation instructions). The Commercialization Report, any advocacy letters, and the additional Cost Volume itemized listing (a-i) will not count against the 50 page limitation and should be placed as the last pages of the Topic Proposal file uploaded. (Note: Only one file can be uploaded to the DoD submission site. Ensure this single file includes your complete Technical Volume and the additional Cost Volume information.) The preferred format for submission of proposals is Portable Document Format (.pdf). Graphics must be distinguishable in black and white. **Please virus-check your submissions**.

AIR FORCE PHASE II ENHANCEMENT PROGRAM

On active Phase II awards, the Air Force may request a Phase II enhancement application package from a limited number of Phase II awardees. In the Air Force program, the outside investment funding must be from a Government source, usually the Air Force or other military service. The selected enhancements will extend the existing Phase II contract awards for up to one year. The Air Force will provide matching STTR funds, up to a maximum of $750,000, to non-STTR Government funds. If requested to submit a Phase II enhancement application package, it must be submitted through the DoD Submission Web site at www.dodsbir.net/submission. Contact the local awarding organization SBIR/STTR Program Manager.

AIR FORCE STTR PROGRAM MANAGEMENT IMPROVEMENTS

The Air Force reserves the right to modify the Phase II submission requirements. Should the requirements change, all Phase I awardees will be notified. The Air Force also reserves the right to change any administrative procedures at any time to improve management of the Air Force STTR Program.

SUBMISSION OF FINAL REPORTS

All final reports will be submitted to the awarding Air Force organization in accordance with Contract Data Requirements List (CDRL) items. Companies **will not** submit final reports directly to the Defense Technical Information Center (DTIC).

AIR FORCE
15.A Small Business Technology Transfer (STTR)
Non-Disclosure Agreement (NDA) Requirements

DFARS 252.227-7018(b)(8), Rights in Noncommercial Technical Data and Computer Software – Small Business Innovation Research (SBIR) Program (May 2013), allows Government support contractors access to SBIR data without company-to-company NDAs only AFTER the support contractor notifies the SBIR firm of its access to the SBIR data AND the SBIR firm agrees in writing no NDA is necessary. If the SBIR firm does not agree, a company-to-company NDA is required.

"Covered Government support contractor" is defined in 252.227-7018(a)(6) as "a contractor under a contract, the primary purpose of which is *to furnish independent and impartial advice or technical assistance directly to the Government in support of the Government's management and oversight of a program or effort* (rather than to directly furnish an end item or service to accomplish a program or effort), provided that the contractor—

> (i) Is not affiliated with the prime contractor or a first-tier subcontractor on the program or effort, or with any direct competitor of such prime contractor or any such first-tier subcontractor in furnishing end items or services of the type developed or produced on the program or effort; and
>
> (ii) Receives access to the technical data or computer software for performance of a Government contract that contains the clause at 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends."

USE OF SUPPORT CONTRACTORS:

Support contractors may be used to administratively process SBIR documentation or provide technical support related to SBIR contractual efforts to Government Program Offices.

Below, please provide your firm's determination regarding the requirement for company-to-company NDAs to enable access to SBIR documentation by Air Force support contractors. This agreement must be signed and included in your Phase I/II proposal package

☐ YES ☐ NO Non-Disclosure Agreement Required
(If Yes, include your firm's NDA requirements in your proposal)

Company: ______________________ Proposal Number: ______________________

Address: ______________________ City/State/Zip: ______________________

Proposal Title: ____

Name ______________________ Date: ______________________

Title/Position ______________________

Air Force STTR 15.A Topic Index

Air Force STTR 15.A Topic Descriptions

AF15-AT01 TITLE: Biomimetic Design of Morphing Micro Air Vehicles

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To design morphing micro air vehicles (MAVs) capable of autonomously and adaptively changing geometric parameters of structural wings utilizing novel concepts of active materials and biomimetic multifunctional structures.

DESCRIPTION: Over the last two decades, significant research and development work has been conducted on shape changing (i.e., morphing) air vehicles primarily under Air Force and DARPA sponsorship. The morphing wing designs developed under these programs were focused on larger UAVs and incorporated discrete actuators, relatively rigid wing components and segments connected with hinges, stretching skins, etc. By necessity, such vehicle wings require airfoil cross-section thicknesses over large portions of the wing to be fixed, thereby restricting large morphing capability to span, chord and wing area only. As a result, the wing cross-section is not optimal at multiple flight conditions. In contrast, bird wings morph in 3-D with large changes in camber. With continuously shape-changing wings, birds can efficiently deal with the different conditions encountered during flight, reducing the power required to fly. Such capabilities of avian flyers should be adapted to fly and maneuver MAV in constrained and complex environments. The goal of this solicitation is to develop the next generation of morphing MAVs using (1) advanced concepts beyond flapping wing actuation technologies and (2) multifunctional structural designs patterned after bird wings and their efficient flight adaptation capabilities for inspiration. Proposer teams shall demonstrate capabilities to design, fabricate and test the systems.

PHASE I: Develop advanced concepts for novel materials and biomimetic structures for morphing MAV wings which efficiently change shape to optimal configurations for a variety of flight conditions including landing/take-off, cruise, gliding, stability under sudden gusts and rough wind conditions, etc.

PHASE II: Develop representative scale models incorporating sensing/actuation capabilities. Establish novel means of processing active materials into assemblies that reversibly modulate mechanical properties. Confirm aerodynamic performance benefits by wind tunnel testing of prototype MAV.

PHASE III: Assess power efficiency and actuation performance of morphing MAVs by real flight testing. Begin the transition process to operationally useful MAVs addressing the issues of payload, endurance, cost, reliability, etc.

REFERENCES:
1. J. Bowman, et al., “Development of Morphing Aircraft Structures,” AIAA-2007-1730, AIAA SDM Conference, Honolulu, April 2007.

2. A. Jha, et al., “Morphing Aircraft Concepts, Classifications, and Challenges,” SPIE 11th Annual International Conference on Smart Structures and Materials, San Diego, CA 14-18, March 2004.

3. A. García Naranjo, et al., “Aerodynamic performance benefits of utilising camber morphing wings for unmanned air vehicles,” Royal Aeronautical Society Journal, Vol. 117, # 1189, March 2013.

KEYWORDS: morphing, micro air vehicles, bird flight, multifunctional structures, active materials

AF15-AT02 TITLE: Robust Mid-IR Optical Fibers for Extreme Environments

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop robust optical fibers capable of low-loss light transport in the 2-5 micron spectral region in high-stress, high-vibration environments.

DESCRIPTION: Performance and reliability of lasers in high-power, high-stress environments is often limited by thermal and vibration issues due to the use of free-space optics in the laser systems. A desirable solution is to utilize beam confinement to make the laser immune to such effects. Development of passive fibers for transport of laser energy between optical components and around the platform would be a great advance in laser design. These fibers would allow for routing of high power/energy laser output in the critical atmospheric transmission windows around 2-5 microns wavelength. Fibers of appropriate composition should be robust and reliable so that they can be made insensitive to temperature changes, vibration, and moisture. Propagation through fiber reduces the alignment issues of free-space optics. Fiber also allows beam transport in confined spaces without need for unobstructed line-of-sight spaces. Fiber strength and resistance to mechanical damage would also be key.

Current fiber capabilities at these wavelengths are limited by either water absorption or other losses. In addition, fiber strength and ability to withstand adverse environments is an issue. New technology is required to advance the state of the art in mid-IR fibers to fulfill Air Force requirements. Of particular interest would be methods for providing beam confinement in IR transmissive materials with high performance characteristics. The ability of the material to withstand representative stresses and survive in the extreme environments found in Air Force applications would also be of interest.

The development, characterization and demonstration of fiber production, IR transmission and advantageous material properties of fibers would be key elements of any proposed research. The ability to integrate these fibers with traditional fiber components, such as connectors, multiplexers, other fibers and switches, would be advantageous. Efforts are needed to develop novel approaches to achieving development of these fibers and maturation of the technology and manufacturing base. The end result of this research would be optical fibers to advance the state of the art in mid-IR laser applications.

PHASE I: Phase I shall demonstrate feasibility of approach to produce optical fibers capable of low-loss (< 1 dB/m) transmission between 2-5 microns that exceeds current state of the art. Demonstration and measurement of physical properties such as fiber strength and resistance to the environment would be important.

PHASE II: The Phase II effort shall demonstrate production of usable lengths of mid-IR fiber for transport of high power (> 100 W) laser output in the 2-5 micron region with less than 0.5 dB/m loss, with bend radii < 10 cm and high material strength. Integration of with active laser systems in a monolithic fashion would be important. Survivability of fibers under representative stress (such as applicable Mil-Specs) should be demonstrated.

PHASE III: Commercialization of process in Phase III would be achieved through collaborations with IRCM and laser radar system vendors to integrate fibers as replacements for free space optics.

REFERENCES:
1. Dan L. Rhonehouse; Jie Zong; Dan Nguyen; Rajesh Thapa; Kort Wiersma, et al. "Low loss, wide transparency, robust tellurite glass fibers for mid-IR (2 - 5 μm) applications," Proc. SPIE 8898, Technologies for Optical Countermeasures X; and High-Power Lasers 2013: Technology and Systems, 88980D (October 15, 2013); doi:10.1117/12.2033925; http://dx.doi.org/10.1117/12.2033925.

2. Rafael R. Gattass; Frederic H. Kung; Lynda E. Busse; L. Brandon Shaw and Jasbinder S. Sanghera, "Bend loss in multimode chalcogenide fiber at infrared wavelengths," Opt. Eng. 53(1), 010502 (January 13, 2014); http://dx.doi.org/10.1117/1.OE.53.1.010502.

3. J. C. Knight and F. Yu, "Silica Hollow Core Fibers for Mid-IR Wavelengths," in Workshop on Specialty Optical Fibers and their Applications, (Optical Society of America, 2013), paper T2.1.

KEYWORDS: Fibers, Mid-IR, chalcogenide, extreme environments, infrared

AF15-AT03 TITLE: Alternative Materials for High Temperature, High Pressure Wind Tunnel Nozzle Applications

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop mechanical properties database at high pressures and temperatures for candidate materials. Design and fabricate nozzle components suitable for use in a production high speed flow facility.

DESCRIPTION: High speed aerospace ground test airflow facilities commonly use beryllium copper (BeCu2) for high temperature and high pressure flow applications as it provides a nominal balance of strength, performance, and machinability. However, beryllium is fairly rare, brittle (making it difficult to shape), and its dust can cause a life-threatening allergic disease called berylliosis. Therefore, alternatives to this material are being sought. The task is to identify alternative materials to beryllium copper for use in aerospace ground test flow facilities. The alternatives should provide similar thermal strength properties as BeCu2, but be less hazardous to fabricate and more readily available. The candidate materials need to withstand high temperatures (minimum 1000 degrees F) and high pressures (minimum 2000 psi); however, materials and implementations that can withstand 3000 degrees F and higher temperatures are ultimately desired.

The effort will consist of analysis and test. The material properties should be analyzed and compared to BeCu2 as a baseline. The trade study should also compare the relative cost of each alternative. All work will be monitored by subject matter experts.

During Phase I, candidate materials for use as high temperature, high pressure wind tunnel nozzles will be identified and evaluated. Analysis will be accomplished using ANSYS software. Testing in a government test facility or suitable third-party laboratory will be initiated.

During Phase II, Thorough testing of candidate materials in a government test facility or suitable third-party laboratory will be required. Mechanical properties will be evaluated while at high temperatures and pressures. Test results to be compared to ANSYS analysis. Candidate components for use as wind tunnel nozzles will be fabricated, tested, and assessed. Finalize selections then design, fabricate, deliver, and demonstrate nozzle at AF facility at the end of Phase II.

PHASE I: Candidate materials for use as high temperature, high pressure wind tunnel nozzles will be identified and evaluated. Analysis will be accomplished using ANSYS software. Testing in a government test facility or suitable third-party laboratory will be initiated.

PHASE II: Thorough testing of candidate materials in a government test facility or suitable third-party laboratory will be required. Mechanical properties will be evaluated while at high temperatures and pressures. Test results to be compared to ANSYS analysis. Candidate components for use as wind tunnel nozzles will be fabricated, tested, and assessed. Finalize selections then design, fabricate, deliver, and demonstrate nozzle at Air Force facility at the end of Phase II.

PHASE III: Hardware for use in Air Force test facilities will be designed and fabricated. Validation will take place in Air Force test facilities. Potential customers include DoD, NASA, universities, and aerospace industry.

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KEYWORDS: materials database, ANSYS, high temperature materials, materials testing

AF15-AT05 TITLE: <u>Tool to Predict High-Power Electromagnetic Effects on Mobile Targets</u>

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a model and associated computational tool (Directed RF Energy Assessment Model 2, or DREAM2) that describes and predicts the effects of a high-power electromagnetic signal on a mobile target, to improve on the existing DREAM tool.

DESCRIPTION: The Air Force has a need to model the effects for a high-power electromagnetic weapon engaging a mobile target such as an aircraft or a missile. Currently the engagement modeling tool used for this purpose is the Joint RF Effects Model (JREM), which is a combination of the Radio Frequency Propagation and Target Effects Code (RF-PROTEC) and the Directed RF Energy Assessment Model (DREAM) [1]. Specifically, the target effects are calculated using the DREAM model, which is based on identifying ports of entry (POEs) whereby RF energy enters the target, identifying the critical susceptible components or subsystems and the associated failure modes and fault tree, and determining the path loss between each POE and the associated crucial component. This last piece, the path loss, has severe limitation since it has to be provided as a user input, rather than being calculated, and the susceptibility calculated by DREAM is strongly dependent on the value of this parameter.

The original DREAM model, which will be available, was developed fifteen years ago and has been applied to many problems of interest to the Air Force. In the intervening years, however, there has been significant progress in modeling and predicting effects on electronics. New electromagnetic computational tools have been developed that make use of increased computer speed and increased storage, and hence large-scale simulations are routinely accomplished that were impossible fifteen years ago. In addition, the area of RF effects on electronics has seen significant progress in the last ten years, both in the US and overseas [2]. An example is the research performed under the RF Effects MURI [3, 4] between 2001 and 2006, which included basic research into RF effects on digital electronics [5], as well as the development of new approaches and tools for computational electromagnetics. One specific example relevant to mobile targets is the Random Coupling Model (RCM) [6], which is used to calculate probability density functions for voltages and currents induced on traces inside a cavity whose dimensions are at least several wavelengths. In addition, there have been significant improvements in the area of network and failure mode modeling, which could potentially be incorporated in an updated model. Finally, the emergence of new generations of electronics will necessitate updating the susceptibility data for analog and digital components and circuits within DREAM, although this task probably lies outside the scope of the current topic.

PHASE I: Conduct review of available methods and tools, and develop plan to build and test updated DREAM model. Plan should address any necessary modeling, development of algorithms for DREAM2 tool, implementation of initial computer code and testing of results for one system.

PHASE II: Develop algorithms for DREAM2 tool and implement in prototype computer code. Apply code to predict effects for one specific system, and test against observed effects.

PHASE III: The development of an improved tool to predict RF effects on a mobile target has both military and civilian applications:

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2. S. Korte1, F. Sabath and H. Garbe, "Analytical Estimation of the Threat of IEMI to Electronic Systems," Proceedings of URSI 29th General Assembly, Chicago IL (2009).

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KEYWORDS: susceptibility, EMI, circuit boards

AF15-AT06 TITLE: Chalcogenide Glass Mid-IR Optic Development

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The objective is to develop mid-Infrared (MWIR) and Infrared (IR) chalcogenide glass optical components for quantum cascade lasers (QCLs), high energy pulsed solid-state lasers, optical fibers, along with other DoD and commercial applications.

DESCRIPTION: In the case of QCLs, which lase from 4.5µm to beyond 10µm, cylindrical micro-lenses with a high numerical aperture are required to collimate the fast axis of the laser. Such lenses are not known to exist presently. The Air Force Research Laboratory also has an interest in the development of MWIR solid state lasers. High energy pulsed Lasers at 4.5µm made from Fe:ZnSe are one option, and this material is pumped at 3µm. These particular lasers will require high damage threshold optics. The surface optical damage threshold for chalcogenide glasses is near 9 GW/cm2 [4]. It is important that bulk and surface damage thresholds be characterized and increased above this level.For both laser and pump, optics with a low absorption coefficient, high damage threshold, and low thermal lensing characteristics are needed.

PHASE I: The contractor will design, develop, and manufacture proof-of-concept chalcogenide lenses applicable for micro-lenses application (dimensions approximately 2mm wide x 2mm high x 3mm long.) with a focal length ~2mm & NA ~0.8. Efforts in improving chalcogenide glass (damage thresholds and absortance) will occur. Test samples will be made (target wavelength of 4.6µm) and delivered to AFRL/RDL.

PHASE II: Phase II will advance the manufacturability and fieldability of the proof-of-concept lense systems. By the end of Phase II production mode for cylindrical QCL collimators will be in place including AR coatings and some form of edge metallization (or mount) for die-bond attachment to submounts. Designs will be for 4µm to 5µm and also from 9µm to 11µm. Delivery of lenses will be made to AFRL/RDL.

PHASE III: In Phase III, production of various sizes of cylindrical lenses will take place. Other components such as fiber end-caps will be delivered. Low absorbing lenses suitable for high energy pulsed lasers will be manufactured.

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KEYWORDS: microlenses, chalcogenide, optics, MWIR

AF15-AT07 TITLE: Additive Manufacturing Plastic Materials with Improved Dielectric Breakdown Strength

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop techniques to develop high dielectric strength additive manufacturing (AM) plastics capable of holding off greater than 20 kV/mm per ASTM D149.

DESCRIPTION: One of the limiting factors on the power output from HPM sources is the high voltage insulator from the pulsed power driving the source. By carefully choosing the geometry of a high voltage insulator to minimize electric field stresses, the overall size of the insulator interface can be reduced, thus allowing for a more compact HPM source. While the ability to fabricate arbitrarily complex insulator geometry for field shaping purposes is an alluring property of printed plastics, the current generation of thermoplastic and stereolithographic resins utilized in AM is known to have significantly lower dielectric breakdown strength than many traditionally fabricated parts from bulk virgin plastics, such as HDPE, Teflon, and Ultem.

In order to take full advantage of the capabilities offered by AM techniques, methods to enhance the dielectric breakdown strength of printed plastic insulators must be developed. These methods may include chemical modifications to the AM resins and thermoplastics, enhanced printing methods to reduce voids and other unwanted defects in printed structures, or post-processing treatments. It must be emphasized that any additional manufacturing steps developed to reach the desired dielectric breakdown strength must not negate the utility of using an AM process to fabricate the insulator compared to using standard subtractive machining of conventional plastics.

PHASE I: Develop a concept to address the poor voltage handling capabilities of printed plastic insulators and methods whereby this concept may be reasonably implemented in the fabrication of high voltage insulators. The concept must demonstrate a viable development path toward the objective of developing high dielectric strength AM plastics capable of holding off greater than 20 kV/mm per ASTM D149 for a 3.175 mm thick sample.

PHASE II: Fabricate high voltage insulators, including vacuum interfaces using AM techniques and experimentally demonstrate the performance of these insulators in comparison to those made using conventional manufacturing techniques (> 20 kV/mm per ASTM D149).

PHASE III: Phase III efforts would focus on technology transition for dual use domestic applications to commercial and DOD systems.

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KEYWORDS: Additive Manufacturing, high voltage insulator, vacuum interface

AF15-AT12 TITLE: Broad Spectrum Optical Property Characterization

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a flexible broad-band optical spectroscopy device along with data acquisition and analysis software.

DESCRIPTION: Recent advances in compact light sources, fiber optics, and computational optics, along with a continual advancement in spectral imaging technologies, are enabling a variety of imaging and spectroscopy methods for biomedical optics, atmospheric sensing, and environmental monitoring. These technologies have focused on application-specific engineering solutions such as the detection of fluorescence signatures during medical procedures, sensitive detection of contaminates in liquid or gas samples, or fiber-based measurement of optical properties. General laboratory needs for product research and development require low-cost, flexible measurement options which can function broadly during prototyping and basic research. Rather than multiple costly systems, this exploratory research requires a single, low-cost system with high sensitivity, broad spectral capabilities, and modest resolution for common measurements.

Developing a flexible low-cost, integrated, sensitive Broad Spectrum Optical Property Characterization System enables the completion of numerous research goals common to the Department of Defense, and within the associated industrial and research and development (R&D) base, as well as medical, environmental, manufacturing, and academic facilities. Prototype point sensors, hyper spectral imaging techniques, as well as material characterizations, can be quickly evaluated for feasibility prior to the application-specific product development. In particular, the need for broad spectral response is currently limited by single detector types within systems, or is limited by single light sources. In addition, additional engineering is required to adapt these systems to surface contact, liquid sample, or gas samples.

This topic seeks to explore the development of materiel approaches for such an optical characterization system. The program will establish a solution space for system development and explore a variety of approaches to meet cost, size, and capability performance parameters. The focus will be on the transition of emerging hardware and theory to develop the next generation in basic laboratory spectroscopic capability.

The system will be required to rapidly acquire data from solids (including living tissues), liquids and gases to obtain optical properties including absorption, scattering, fluorescence, and Raman response data. Absorption and scattering properties over a wavelength range of 300nm to 2,000 nm is desired, along with fluorescence response from blue-violet wavelength excitation. Raman excitation from blue-violet and red wavelength regions is also desired. The system should be compact and lab portable, should include surface contact or system-mounted measurement options. The collection of data and extraction of optical parameters and spectral analysis are required within the system software.

PHASE I: Develop concepts for hardware and instrumentation software to enable a broad spectrum optical characterization system, capable of point measurement of optical properties along with fluorescence, absorption, and Raman spectra. The design will include capabilities for surface-contact measurement, liquid samples over a wide range of optical properties, and approaches for evaluating gas-phase samples.

PHASE II: Based upon the results of Phase I and the Phase II development plan, the company will develop a prototype for evaluation by the Directed Energy Bioeffects Program or another program as specified by the sponsor. The prototype will be evaluated to determine its capability in meeting the performance goals defined in the Phase II development plan and the requirements outlined in this description.

PHASE III: Applications for this technology are biomedical optics, analytical chemistry, materials manufacturing characterization, environmental monitoring, education, and general R&D. The system will have applicability for exploratory research & engineering, guiding future product development.

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2. A. Kim, et al., “Quantification of in vivo fluorescence decoupled from the effects of tissue optical properties using fiber-optic spectroscopy measurements,” J. Biomed. Opt., 15(6), 067006 (2010).

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KEYWORDS: spectral imaging, optical characterization, broad spectral, absorption, scattering, fluorescence

AF15-AT13 TITLE: Low-Latency Embedded Vision Processor (LLEVS)

TECHNOLOGY AREAS: Human Systems

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OBJECTIVE: Develop architectures for an embedded processor capable of implementing the image processing algorithms required for a digital helmet-mounted display for dismounted soldiers.

DESCRIPTION: High-performance, low-power, and low-latency processing is needed to perform image processing algorithms in next-generation aircraft helmet systems. New architectures and technologies are needed to respond to issues arising due to continued shrinking of semiconductor fabrication process geometries. Existing approaches have not satisfied end-user needs, such as multi-channel I/O, low-latency, large image sizes, and high frame rates. Novel architectures are needed, and alternatives promising improved power efficiencies of the processor clock tree, logic, memory, and chip I/O must be investigated. Familiarity with the important algorithms, such as distortion correction, multi-spectral/multi-modal fusion, and head-tracking, is required to ensure the solution can meet the challenging performance requirements. Consideration must also be given to the robustness of the processor, as a warfighter’s life may depend on its reliability in a challenging electromagnetic radiating environment. Finally, consideration must be given to a solution that can not only be applied to the digital binocular helmet-mounted display, but also to a wider set of applications that can take advantage of high-performance, low-power, low-latency image processing. The processor requirements for the vision processor ASIC developed under the DARPA Multispectral Adaptive Networked Tactical Imaging System (MANTIS) program (2003-2010) is a good example. It was originally conceived to fuse inputs from five helmet-mounted electro-optical sensors operating in the visible-near infrared (VNIR x 2), short wave infrared (SWIR x 2), and long wave infrared (LWIR) bands and generate two synchronized SXGA video outputs at 60 Hz to a pair of microdisplays. However, it resulted in a processor that ingested three sensors (one each VNIR, SWIR, LWIR) and generated just one video output at 30 Hz due to the technical approach (e.g., architecture, microelectronic technologies) and processor geometry (90 nm) used at the time [1]. Under this program, a vision processor for helmet systems (VPHS) is required to enable the design and fabrication of a digital binocular helmet-mounted display (HMD) having all source image fusion with two video outputs. Binocular systems needed by warfighters require threshold (objective) performance comprising two synchronized video outputs, each at 60 Hz x 1.3 Mpx/frame x 8b/px = 0.624 Gbps (5Mpx x 8b x 96Hz = 3.84 Gbps), and must be capable of ingesting matching resolution video (in Mbps) from multiple sources (on-helmet or on-aircraft) comprising various mixtures of live video from sensors, synthetic imagery, and overlay symbology. Monocular systems with similar processing requirements are also of interest. To understand the power and latency impacts of a total solution, it is necessary to both demonstrate a representative set of algorithms on the proposed processor, and to measure the system level performance, including required peripherals, such as external memory. Demonstrated success against a metric, such as GOPS/W or GFLOPS/W, is not sufficient, as it only provides a partial picture of a solution, potentially pushing off the power requirements and demanding physical capabilities to other parts of the system.

PHASE I: Based upon existing data, develop two plans to design and fabricate a VPHS, one containing a high-risk approach and one containing a low-risk approach. Estimate the power, frame latency, weight, and size of each of the processors and any peripheral devices. Clearly identify the risks and benefits associated with each approach. Binocular and monocular VPHS applications are both of interest.

PHASE II: Design a prototype VPHS. Perform a simulation of the proposed VPHS design that demonstrates the threshold (objective) capability to process the outputs of two 1.3Mpx 14b 60Hz (5Mpx 14b 96Hz) sensor outputs through a representative set of imaging and display algorithms to drive two synchronized 1.3Mpx 8b 60Hz (5Mpx 8b 96Hz) microdisplays with less than 1-frame latency.

PHASE III: Fabricate a prototype VPHS and demonstrate threshold (objective) capability to process two 1.3Mpx 14b 60Hz (5Mpx 14b 96Hz) VNIR sensor outputs through a representative set of imaging and display algorithms to drive two 1.3Mpx 8b 60Hz (5Mpx 8b 96Hz) flat panel displays with less than 1-frame latency.

REFERENCES:

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KEYWORDS: vision processor, algorithms, low-latency video processing, embedded image processor, wearable electronics, helmet-mounted systems, alternative night/day imaging technologies, multi-source image fusion, battlespace visualization, dismounted operations

AF15-AT14 TITLE: Modeling and Simulation for Design, Development, Testing and Evaluation of Autonomous Multi-Agent Models

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To complement capabilities of future autonomous systems, Air Force requires interoperable tools & methodologies to design, verify, validate, assess & operate human-machine system interactions associated with autonomous and manned systems integration.

DESCRIPTION: Autonomous systems have the potential to improve safety and reliability, reduce costs, and enable new missions and services. The development of autonomous systems is becoming a reality with technological advances in computer processing, sensors, and networking. This is now driving the development for a wide variety of applications on the ground, in space, at sea, and in the air. (NRC, 2014). These systems cannot be deployed without careful risk reduction through an analysis of viable alternatives and the early development of verified Concepts of Operation. Today, the systems that might make up an autonomy-enabled operational package are for the most part proprietary and stove-piped. This is the case for ground-based simulation environments and the actual operational systems, as well. Interoperability today is done via data exchanges and gateways and the application of common industry standards for data sharing and environment integration. With the integration of autonomous systems with manned systems, we need to ensure that this interoperable capability is coupled to a human and machine teaming and trust construct and these are collectively driven into system design, training development and the operational systems.

In order to prepare the Air Force for these future human-machine systems, new forms of autonomy test and evaluation tools are critical to ensure a total system design approach that properly integrates, amplifies, corrects, and leverages the capabilities of both people and machines. Anticipating the context and contribution of human behavior in which technologies are operated and maintained requires shareable and fully interoperable models and valid environments that represent agent architectures and incorporate theories of human perceptual, cognitive, trust, and social systems.

This topic seeks proposals that address research in the following areas. A system design framework with complementary tools that enable analysis of dynamically changing work system configurations (e.g., predicts how pilots handle unexpected situations involving A2AD). A successful proposal would include:
1) Creation of a testbed that simulates an entire environment (e.g., geography, fast jets, and command and control) to create a portable tool to be used to experiment with a wide variety of scenarios and tactics. This testbed will provide an environment that uses industry simulation standards (i.e., Distributed Interactive Simulation)
2) Work practice analysis methods to evaluate autonomous system operations, for example relating varying situation awareness to roles and responsibilities of people and automated systems
3) Architectural designs and methods for developing reconfigurable simulated intelligent red forces that demonstrate predictive capability and can be used in formulating mission concepts of operation, tactics and training
4) Methods to adapt multi-agent simulations to predict adversary actions and to advise maneuvers, to be used as a debriefing tool or potential onboard “pilot assistant”
5) Architectural designs and methods for simulating virtual players that enable replacing humans in the loop (part of “virtual” component in LVC) by simulated players, e.g., simulate and replace AWACS operators or “manned threats”
6) Methods for designing, testing, and operating LVC simulation architectures that incorporate multi-agent and object models for a more flexible, reconfigurable mix of simulated and actual human players, as well as simulated and actual vehicles and other assets
7) Human-systems simulations integrating autonomous systems in current training simulations including LVC-capable simulations amenable to system design, validation, and instruction
8) Computational frameworks for developing agents that learn from experience about how to react to variances from flight tactic templates and learn about contextual behaviors of partners and adversaries

PHASE I: A successful Phase I effort will develop a prototype testbed that simulates an example domain. This will include the completion of the work analysis task to assess autonomous system operations. Additionally architectural designs and methods for developing reconfigurable simulated intelligent red forces that demonstrates predictive capability will be developed.

PHASE II: The Phase II effort will fully develop a testbed that simulates the entire environment (e.g., geography, fast jets, and command and control) and will execute tasks 4-8 as described in the description. A successful Phase II effort will demonstrate tools and methodologies to properly design, verify, validate, assess, and operate human-machine system interactions. The final system will enable analysis for systems that use industry simulation standards (i.e., Distributed Interactive Simulation).

PHASE III: The Phase III effort will integrate the system developed during Phase II into an operationally relevant and interoperable environment to test and evaluate man machine teaming in real-time. The results will be quantified and documented. The final integration will be demonstrated.

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6. Additional Q&A for STTR Topic AF15-AT14 provided by TPOC, uploaded in SITIS 1/15/15.

KEYWORDS: autonomous multi-agent models, human-machine system interactions, industry simulation standards

AF15-AT15 TITLE: Carbon Nanotube Technology for RF Amplification

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a high-linearity Carbon Nanotube Field Effect Transistor (CFET) for RF amplification to dramatically improve the power and spectral efficiencies in wireless communication.

DESCRIPTION: Modern communications systems utilize complex RF modulation schemes to increase spectral efficiency, bits/second/Hz.

Distortions caused by non-linear RF amplifiers directly limit the data rate that can be achieved in a given channel. While methods like pre-distortion and envelope tracking can improve linearity, higher linearity is achieved primarily by increasing the DC current flow/power in the amplifier and modulating the current over a small a linear region. This leads to a direct trade-off between spectral efficiency and power. As a contrast, current transport in CFETs is understood to be inherently linear.

The best CFET device performance reported are fT and fMAX of 25GHz, and 11GHz, respectively, and an OIP3 of 15 dBm measured at 1 GHz. While progress has been made, these are substantially below current state of the art transistors.

Active research on CNT materials issues such as the presence of metallic CNTs and too wide a diameter distribution of semiconducting CNTs are making traction. Developing a working process that can preserve the superior properties of better CNT material in a fabricated device is the subject of this topic. CNT to source/drain contact resistance and channel doping/control are the key process elements needed. If contact resistance is reduced by half, fT can be improved by up to 50 percent. With the right dielectric/doping material in the channel, transconductance and fT can be increased by more than a factor of two. The combination will give well controlled conduction in the CFET allowing the materials intrinsic linearity to be realized.

PHASE I: Develop the baseline process to form low source-drain contact resistance to the CNTs. This includes finding the right metal stack and annealing recipe to form good ohmic contact to the CNTs. The goal is to achieve a resistance less than 25 kO at per nanotube contact. A novel process flow may be needed to reach such goal.

PHASE II: Develop the baseline process to complete the full device fabrication, emphasizing dielectric layer development, including both the material selection and the coating method. The goal is to fabricate hysteresis-free devices with transconductance greater than 20 ÂµS per semiconducting CNT. Demonstrate a prototype L-band amplifier with linearity: power performance comparable to or better than the existing technology using the CFET developed herein.

PHASE III: The CFET developed herein can be used in wireless communication system. The selected company can further pursue for CFET space-qualifying prototype, complete radiation qualification testing data, for potential inclusion in test flight and communications.

REFERENCES:

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5. M. Schrater, M. Claus, P. Sakalas, M. Haferlach, and D. Wang, "Carbon Nanotube FET Technology for Radio-Frequency Electronics: State-of-the-Art Overview," IEEE J. Electron Dev Soc, 1, pp 9-20, (2013).

KEYWORDS: carbon nanotube, CNT, carbon nanotube field effect transistor, CFET, RF amplifier, linearity

AF15-AT16 TITLE: High Quality/Low Dimension Data for Sensor Integration

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To develop methods that produce high quality sensor integration (fusion) with low dimensional data complexity. This methodology will be used to produce near optimal compression of high dimensional data from multiple sensors.

DESCRIPTION: The proliferation of sensor systems has created a large volume of multi-sensor data across a number of physical fields (e.g., optical, EO/IR, hyperspectral, polarimetric, acoustic/seismic, RF, electromagnetic, mechanical, thermal, electrical, radiation) [1]. Simplistic methods often declare detections at the various sensors and integrate these one-bit data information at a central processor [2]. In doing so, much of the important information provided by the multi-sensor data is lost. The result of this low quality data integration is subsequent ineffective detection, localization, and tracking algorithms, relative to what is possible if the full information of the sensors were leveraged.

Recent advances in probability density modeling for the integration of various dimensionality and types of data [3] may allow possible improvements to the more naive methods currently in use. This modeling is based on the results obtained from research into information geometry, which is currently being conducted in many diverse fields [4]. This methodology may provide reduced dimension sensor outputs to be communicated in real time to a central processor for more efficient utilization of the available data sources. A key component of the data integration is to minimize the actual information loss of the reduced dimension and multi-sensor data provided to the central processor. This will benefit the overall system mission by improvements of system signal processing performance by utilizing the most informative data of the sources for various scenarios. These scenarios may include airborne radar, passive radar, illuminators of opportunity, as well as others.

PHASE I: Identify statistically efficient (highly informative and low dimensional) approaches for combining outputs of disparate sensors to achieve objectives (e.g., detection, localization and tracking). Quantify performance improvements. Use synthetic data sets to demonstrate effectiveness. A baseline approach in common use should be used for performance comparisons.

PHASE II: Further refine and develop the statistical models and sensor fusion algorithms for radar signal processing tasks. Conduct high fidelity demonstration/validation of algorithm performance, based on finer grained simulations. Develop a baseline embedded computing approach for meeting tactical timeline requirements for chosen applications. Quantify performance gains relative to conventional fusion algorithms.

PHASE III: Military applications may include: improved detection, localization, and tracking of various emitters in diverse military scenarios, having potential applicability across the entire DoD ISR enterprise. Commercial applications may include fields such as law enforcement, medical, and automotive.

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KEYWORDS: multi-sensor data fusion, low dimensionality data representations, information measures

AF15-AT17 TITLE: Reverberation Mitigation of Speech

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Research and develop a method to improve the mitigation of reverberation of speech in a communication channel.

DESCRIPTION: One of the problems in speech communication, speech recognition, and speaker recognition is reverberation. Reverberation is mainly due to sound multipath propagation in the surrounding environment. While reverberation does not represent a severe problem when the speaker and the listener are talking face to face to each other in a reverberant environment (such as a hallway), it really represents a serious problem if the speech is recorded first and then played back or if the signal is transmitted and the listener on the other end is trying to understand the speech. Great difficulty can be experienced in understanding the recorded sound; fatigue can also be felt after a while and sometimes parts of the speech are totally missed. This is known as degraded sound intelligibility. The severity of the problem always depends on the environment. Many factors affect how reverberant the environment is, such as the size of the room, type of automobile, the material used in the buildings and so on. Many attempts have been made since the 1960s using different techniques but until now the topic is still an active area of research due to two main reasons: The first is that many of the developed techniques degrade the quality of the original signal after de-reverberation. This represents a serious problem especially if the de-reverberated signal will be used in a successive stage where sound features are extracted to be used in automatic speech or speaker recognition. The second reason is that many techniques depend on the knowledge of the exact effect of the environment, which makes the performance of these techniques suitable only for specific environments, and/or depends on some parameters that cannot be assumed to be known in practical cases. This technology could be applied to military applications such as speech analysis, or to communication telephony (i.e., hands free in an automobile). The goal here is to mitigate the reverberation by measuring the amount of it in the speech, process the signal with the method developed and transmit the clean signal.

PHASE I: Study the reverberation problem. Develop a new algorithm or improve an existing method. Determine the improvement of the new concept and compare to existing methods.

PHASE II: Develop a system that includes the reverberation mitigation algorithm developed in Phase I. Test and demonstrate this system using audio data that has various amount of reverberation. During Phase II, identify a partner with a speech technology company to use with their product, such as mobile phone companies. The contractor needs to address the cost and schedule of the commercialization of the reverberation mitigation application.

PHASE III: A reverberation mitigation technique would be useful for both military and commercial use. This product would be beneficial for applications such as speaker identification that is used heavily in today's military, and hand free cell phone users speaking in various environments.

REFERENCES:
1. B. Yegnanarayana, and P. Satyanarayana Murthy, "Enhancement of reverberant speech using LP residual signal," IEEE transactions on speech and audio processing, Vol. 8, No.3, May 2000.

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KEYWORDS: speech enhancement, reverberation, echo cancellation

AF15-AT19 TITLE: Active Control of a Scramjet Engine

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a closed-loop engine control system to manage critical scramjet transients and improve overall operability and performance. All aspects of an integrated engine control system (i.e., sensors, actuators, and algorithms) should be considered.

DESCRIPTION: Current scramjet engine control schemes are extremely conservative. Operability margin is built into the system through a long isolator. Transients such as engine ignition, acceleration, and mode changes that occur at high flight Mach numbers are managed via the generously sized isolator and a cautious fuel schedule. Little effort has been applied to developing a control system that supports rapid engine start and aggressive acceleration; no effort has been applied to optimizing engine performance during the course of a flight. An active control system in scramjet engines with appropriate sensors, responsive actuators, and robust algorithms provides a method for improving overall engine operability and performance, which are common in more traditional engines such as the gas turbine.

An effective control system is dependent on the quality and timeliness of inputs to the controller as well as the effectiveness of those inputs in conveying an engine state or pending state change. The system is dependent on the effectiveness of the engine plant model and the algorithm that takes the input and, based on the modeled response, determines and commands a necessary action. Available actions are limited in current, fixed geometry scramjets. Total fuel flow rate can be adjusted, fuel reactivity can be modified, fuel injection sites can be changed, and the characteristics of the incoming boundary layer can be manipulated (for example, energized or bled).

The operating environment within a scramjet combustor is harsh: peak gas temperatures are near 3000 degrees F, flowpath walls operate close to their maximum use temperature, peak pressures are near 100 psia, and vibration levels are significant. Control measurements must be made in such environments; actuators must perform reliably in such environments. The entire sense/comprehend/actuate process must be sufficiently rapid to manage the expected transients. Ignition, flame blowout, and inlet unstart occur on the order of ms; while acceleration-driven transients will be 3 orders of magnitude slower. The weak link in the process, with respect to speed, is expected to be the actuator. Actuator response times of 10 ms or less are likely necessary on roughly 10 percent of the transients expected for a given mission. The use of nontraditional actuators (e.g., plasmas, pizeo, electrical discharges, etc.) may be required.

Algorithms developed should be robust and capable of responding to both fast (10 ms time scale) and slow (greater than 1 s time scale) disturbances to the engine flowfield. Prototype models of the scramjet plant can be made available to those proposals selected for award. Depending on the offeror’s specific strategy, these may or may not be adequate.

PHASE I: Demonstrate the feasibility of an innovative, closed-loop control system for use in the scramjet combustion environment described. Identify a path, including technology readiness levels (TRLs), for development and application of the technology. Feasibility can be demonstrated via numerical analysis or testing.

PHASE II: Fully develop the closed-loop control system proposed during Phase I and fabricate test rigs or hardware that are necessary to confirm Phase I predictions within a laboratory environment.

PHASE III: High-speed propulsion systems and technologies are applicable toward time-critical weapon systems, strike/reconnaissance vehicles, and space launch applications. Enhancement of current scramjet system designs is needed to enable access to space applications to compete with existing rocket platforms.

REFERENCES:
1. Srikant, S., Wagner, J.L., Valdivia, A., Akella, M.R., and Clemens, N.T., "Unstart Detection in a Simplified-Geometry Hypersonic Inlet-Isolator Flow," Journal of Propulsion and Power, Vol. 26, No. 5, 2010, pp. 1059-1071.

2. Hutzel, J. R., "Scramjet Isolator Modeling and Control," Ph.D. thesis, Air Force Institute of Technology, December 2011.

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KEYWORDS: hypersonic, scramjet, propulsion, sensors, actuators, control system

AF15-AT20 TITLE: <u>Measurement of Molecular Energy Distributions and Species Concentrations at MHz Rates in Turbulent Combusting and Nonequilibrium Flows</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop spectroscopic tools for demonstrating spatially and temporally resolved, high-bandwidth (MHz-rate) measurements of molecular energy distributions and major species concentrations in turbulent combusting or nonequilibrium flows.

DESCRIPTION: Spatially and temporally resolved measurements of molecular energy distributions and major species concentrations in combustion and turbulent non-equilibrium flows are necessary to ensure accurate modeling of flow physics and chemistry. To investigate the structure of reaction fields in combustion or measure the molecular distribution of energy in test-vehicle boundary layers, point/planar measurements at MHz rates are required. MHz-rate in situ measurements of vibrational and rotational energy distributions along with mole or mass fractions of major species (N2, O2, H2) will allow unprecedented insight into energy transfer and reaction progress in non-equilibrium flows. Such measurements must be spatially resolved at a point, along a line, or in a plane with sufficient temporal resolution (sub-µs) to freeze the flow; furthermore, such measurements should not require flow seeding.

Molecular energy distributions and major species could be tracked via various spectroscopic techniques such as spontaneous Raman, coherent anti-Stokes Raman scattering (CARS), Raman-excited laser-induced electronic fluorescence (RELIEF), and laser-induced fluorescence. Especially under some supersonic conditions (e.g., in detonation-based combustion devices), it is essential to measure vibrational and rotational temperature from the distribution of molecular energy states that are not necessarily in equilibrium and also measure concentrations of O2 and H2 to assess local fuel-air ratio. Similarly, improved measurements of molecular energy distributions in hypersonic boundary layers will enhance the fidelity of numerical simulations of the extreme pressures and temperatures in the Mach 8+ operational envelope of hypersonic systems. Current state-of-the-art technology is incapable of providing high-fidelity spatially resolved temperature and species measurements at a rate greater than 10 kHz. Though measurements at rates of 50 kHz or greater are possible through high-bandwidth atomic or molecular spectroscopy using tunable diode lasers, they are limited by inherent averaging along a line-of-sight and temporal averaging over the µs-duration tuning. Two-line planar laser-induced fluorescence (PLIF) of a single species can provide temperature measurement based on relative population distributions in a 2D plane; however, the uncertainty in PLIF-based thermometry can be as high as 30 percent without detailed knowledge of the local chemistry. The objective of this effort is to develop high-repetition-rate, spatially and temporally resolved spectroscopic tools for measuring rotational and vibrational temperature and major species in turbulent or combusting nonequilibrium flows at MHz rates. The techniques developed should have a continuous, temporal interrogation length of at least 10 ms to encompass the run time of some detonation events and typical high-enthalpy shock facilities used for hypersonic experimentation.

In order to successfully perform the work described in this topic area, offerors may request to utilize unique facilities/equipment in the possession of the U.S. Government located at Wright-Patterson Air Force Base, Ohio, during the Phase II effort. Accordingly, base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability. The facilities available for base support may include instrumentation and test facilities at Wright-Patterson Air Force Base in the Combustion and Laser Diagnostics Research Center (CLDRC).

PHASE I: Demonstrate laser-based, spatially (point, line, or planar) and temporally (sub-µs) resolved measurements of rotational and vibrational energy distributions and major species concentrations in nonequilibrium flows at a rate of 1 MHz.

PHASE II: Further develop the technology demonstrated during the Phase I research effort and demonstrate in a combustion and/or boundary-layer applications of AFRL interest such as pulsed-detonation combustors, rotating detonation engines, scramjets, and/or hypersonic vehicles. Develop and deliver hardware and software for data acquisition in relevant facilities and efficient and intelligent interpretation of the spectroscopic signals acquired during the Phase I and Phase II research efforts.

PHASE III: These measurement technologies will be used for improving design practices, acquiring validation-quality data, mitigating program risk, and enhancing weapon-system sustainability with applications in gas-turbine combustion, detonation-based devices, IC engines, and turbine-engine test facilities.

REFERENCES:
1. G. Magnotti, A.D. Cutler, and P.M. Danehy, "Development of a dual-pump coherent anti-Stokes Raman spectroscopy system for measurements in supersonic combustion," Appl. Opt. 52, 4779–4791 (2013).

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KEYWORDS: molecular energy distributions, nonequilibrium, combustion, high-bandwidth measurements, ultrashort-pulse laser spectroscopy, pulse-burst lasers

AF15-AT21 TITLE: Prediction and Measurement of the Soot Build-Up in Film-Cooled Rocket Engines

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop validated chemical-kinetics models for kerosene pyrolysis/soot formation at conditions representative of LRE thrust chambers. Develop technique for in-situ measurement of carbon deposition to formulate and validate models.

DESCRIPTION: Advanced physics-based modeling and simulation tools are playing an increasingly important role in the design of high performing combustion devices for Air Force propulsion systems such as rockets, gas turbines and scramjets. Highly energetic systems such as rockets and scramjets, in particular, require advanced thermal management comprised of regenerative cooling passages in the combustor walls and/or fuel film cooling on the hot-side of the combustor [1]. Design of such thermal management systems requires the accurate and efficient prediction of thermal and structural responses of the engine hardware with the combusting fluid dynamics, including fluid and surface chemical kinetics, thermal barrier coating effects [2], convective (turbulent or laminar) and radiative heat transfer, soot formation and deposition.

DoD is interested in advancing the modeling of chemically reacting and sooting flow which results when a fuel film is used to protect a rocket combustion chamber wall. Reaction mechanisms for kerosene pyrolysis found in the literature generally involve hundreds of chemical species and thousands of elementary reactions of known Arrhenius rates. Soot formation also includes the sub-processes of particle inception, surface growth, oxidation, and coagulation. Validated modeling and simulation tools are needed in order to develop optimized combustion chamber designs. Models must be modular and suitable for incorporation into a multiphysics computational environment with highly scalable, parallel-processing architecture.

PHASE I: Demonstrate feasibility of validated models of pyrolysis, soot formation, and carbon deposition in kerosene film-cooled rocket engine combustion chambers within a CFD framework. Perform proof-of-concept experiments that demonstrate the feasibility of a model validation method based on measurements of carbon deposition and/or the physical variables that control the deposition.

PHASE II: Develop and validate a physics-based model suitable for COTS/research CFD software for the prediction of the formation of soot and carbon wall deposits in kerosene film-cooled rocket engines. Develop a technique for in-situ measurement of carbon deposition and/or the physical variables that control the deposition for use in formulating and validating models. Deliverables will include the software models and the equipment for performing the validation measurements.

PHASE III: The capability to predict hydrocarbon pyrolysis, soot formation and carbon deposition is applicable also to scramjet fuel cooling and in the chemical process industry for processes such as the manufacture of carbon black.

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KEYWORDS: liquid rocket engine, combustion chamber, chemical kinetics, pyrolysis, soot

AF15-AT22 TITLE: <u>Plasma Generator for Controlled Enhancement of the Ionosphere</u>

TECHNOLOGY AREAS: Battlespace

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Identify suitable materials and model, design and build a light-weight throttleable directional mechanism for controlled production and dispersal of artificial plasma into the space environment.

DESCRIPTION: The natural ionosphere has a variety of effects on radio propagation. Some of these, such as scintillation, are disruptive to the function of RF systems that depend on transionospheric propagation, while other effects, such as refraction and reflection, are the key enabling effects that allow systems to operate, especially at lower frequencies. Some of the deleterious effects of the ionosphere on systems can be overcome by adding plasma to the environment to smooth out irregularities or prevent conditions necessary for development of turbulence. Artificial plasmas can also be used to directly enhance system performance by enabling propagation paths not possible in the natural environment. Artificial plasma production using high-power transmitters has been envisioned for many decades (Koert, 1991), and demonstrated at relatively low densities using ground-based facilities (Pedersen et al., 2010), but the large investment in transmitter infrastructure required limits practical applications of these techniques. Plasma enhancement by chemical means, such as barium releases or chemionization, overcomes many of these logistical difficulties. But current technologies for chemical releases are typically limited to impulsive dispersal leading to initially spherical clouds or continuous dispersal producing an elongated trail along the trajectory of the host vehicle, as in TMA releases. The fraction of the payload taken up by the canisters, dispersal system, and energy source is also very high, leaving as little as 10% of the mass for the actual plasma-producing material. Innovative techniques that could achieve high ionization efficiency, high payload mass fraction, and controlled dispersal patterns both in time and space are needed to begin development of practical applications of artificial plasma techniques. Early stages of this effort would require modeling of material properties and ionization and dispersal processes, while later stages would involve design and construction of a prototype that could be used to demonstrate functionality in the space environment. Designs that could be readily accommodated on a variety of vehicles, such as by fitting within cubesat form factors, are strongly preferred. Successful proposers must demonstrate solid understanding of the various processes involved in producing artificial space plasmas, including generation of gas-phase substances, ionization and recombination reactions in the space environment, expansion and diffusion of neutral and ion clouds, plasma flow across and along the magnetic field, and avoidance of byproducts which could quench the plasma.

PHASE I: Survey possible means and materials for efficiently enhancing plasma densities in the space environment and develop a model to predict the reaction and dispersal of various potential materials in space. Develop conceptual designs for a throttleable steerable release system compatible with one or more candidate materials that could produce a controlled distribution of artificial plasma.

PHASE II: Using the model and simulations from Phase I, design, construct, and deliver a throttleable directional plasma generator device suitable for testing in large vacuum chambers or on an actual flight. The prototype shall include sufficient reactant, fuel, or other consumable material to produce at least 10^25 total ion-electron pairs in a single test. Prototype systems capable of operating with more than one material and including multiple reactant packages for testing are highly preferred.

PHASE III: Plasma generators could be used to smooth out ionospheric disturbances to assure reliable communications and navigation in theater, or to provide novel capabilities for RF systems. Advanced plasma generators could also replace civilian systems used as tracers in various upper atmospheric research.

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KEYWORDS: Space plasmas, RF propagation in plasmas, plasma generation techniques, ionospheric radio propagation, plasma cloud modeling, chemical ionization

AF15-AT23 TITLE: <u>Spectrum Sensing and Sharing by Cognitive Radios in Position, Navigation and Timing (PNT) Systems</u>

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Design, model, and validate cognitive radio technology to mitigate limited licensed spectrum by accessing efficiently unlicensed spectrum bands in support of military space based PNT needs on a non-interference basis.

DESCRIPTION: Within the current spectrum framework, most of the spectrum bands are exclusively allocated to specific licensed services. However, many licensed bands, such as those for TV broadcasting, are underutilized, resulting in spectrum wastage [ref 2]. This has encouraged the FCC to open the licensed bands to unlicensed users using cognitive radio (CR) technology [ref 3].

To do so, the unlicensed users or secondary users (SUs), need to monitor the activities of the licensed users or primary users (PUs), to find spectrum holes (SHs), which are defined as the spectrum bands that can be used by the SUs without interfering with the PUs. This procedure is called spectrum sensing [ref 4-7]. There are two types of SHs, temporal and spatial SHs [ref 5]. A temporal SH appears when there is no PU transmission during a certain time period and the SUs can use the spectrum for transmission. A spatial SH appears when the PU transmission is within an area and the SUs can use the spectrum outside that area. For this application, hostile jamming can also be considered a class of PU, in that such interference sources are to be avoided.

With CR, the users can recognize the enemy and friendly communications and protect their own. Moreover, the users can search for more transmission opportunities. Prior programs such as SPEAKeasy radio system and next Generation (XG) sought to exploit the benefits of CR techniques. This topic seeks to pursue how PNT ranging signals from space (and potentially ground) sources would employ CR technology.

Offerors should clearly indicate how they are pursuing a local SH sensing system and the SH sensing system's integration into the overall PNT RF system targeting the L, S, and C bands. As frequencies change, transmitted power may have to change in order to maintain the needed carrier-to-noise density ratio. Proposers should indicate how collaborative spectrum sensing (CSS) will be implemented and how the collaboration of several SUs for spectrum sensing will improve the detection performance by taking advantage of independent fading channels and multiuser diversity.

Refs. 1 and 3 should provide a starting point for development of the CR system and the parameters of merit for such a system, specifically:

- Spectrum decision making: consists of two steps. Each spectrum band is characterized, based on not only local observations of CR users but also statistical information of primary networks. Then, based on this characterization, the most appropriate spectrum band can be chosen. For PNT CR systems, primary users must not be interrupted as a primary performance parameter.
- Spectrum mobility in the time domain: how CR networks adapt to the wireless spectrum based on the available bands.
- Spectrum mobility in space: how available bands change as a user/transmitter moves from one place to another.

Notional operations concepts should be developed for local monitoring, control of satellite assets, and coordination with users. Based on proposed decision fusion criteria, CSS can be realized in either a centralized or a distributed manner. Both wideband spectrum sensing and sensing strategies synchronized with other military applications are of topical interest.

This topic does not require trades studies on how to alter the entire Global Positioning System (GPS) constellation and is considering only potential limited augmentations to it.

No use of government materials, equipment, data, or facilities is contemplated in this topic.

PHASE I: Provide a model of how cognitive radio technology would mitigate limited licensed spectrum by accessing efficiently unlicensed spectrum bands in support of military space-based PNT needs, while maintaining needed link budgets. Document how the Phase II effort represents an optimal trades space solution to this need and indicate what the PNT constellation implications would be.

PHASE II: Validate through breadboard CR hardware, software, and algorithm testing how the topic objective would be met. Update the Phase I model using test data and update the constellation trades space study. Determine how and if the concept can be commercialized with a Phase III commercial partner.

PHASE III: Work with a commercial partner to produce and test commercial prototypes supporting the topic needs. Military applications include both PNT systems, communication systems, and electronic warfare systems. Civilian applications would be in PNT systems and communication systems.

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KEYWORDS: cognitive radio, dynamic spectrum sensing, Position Navigation and Timing, PNT

AF15-AT25 This topic has been removed from the solicitation.

AF15-AT26 TITLE: Compact Passive Millimeter Wave Sensor for GPS-denied Navigation

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a compact passive millimeter wave (PMMW) sensor to aid the navigation system of a small unmanned aerial vehicle (UAV) or a guided munition operating in a GPS-denied environment.

DESCRIPTION: In a GPS-denied environment, onboard sensors operating in the visible band can effectively aid a navigation system using Simultaneous Localization and Mapping (SLAM) or georegistration techniques. However, vision sensors have limited utility at night or in fog or rain. Although infrared sensors may be used at night, they, too, have poor performance due to significant signal attenuation in rain and fog. Atmospheric windows exist in the millimeter wave band (at frequencies of 35, 94, 140, and 220 GHz) that have much less attenuation in rain and fog than visible or IR. Thus, a sensor operating in one of these bands that can use optic flow or feature tracking to aid the navigation system is highly desirable as an all-weather solution for GPS-denied operation. Furthermore, a passive system is preferred to minimize the risk of detection by an adversary.

Perhaps the most limiting factor for a PMMW sensor is Rayleigh's criterion, which states that the resolution of a sensor is proportional to wavelength and inversely proportional to detector size. Thus, a PMMW sensor must have a much larger aperture to have the same effective resolution as a visible sensor. Nevertheless, the potential of this technology is very appealing for all weather operation.

We are seeking significant advances in sensor and processing technology that will make a PMMW sensor a viable navigation aid for a small UAV (with a wingspan of 5 meters or less) or a munition. Thus, the sensor must show potential to be compact (approximately 3 kilograms or less) and a reasonable cost. The required effective resolution and field of view of the sensor is currently undefined. It is expected that an analysis will be performed to make appropriate choices. Also, the sensor must be able to deal with the dynamic motion of these types of vehicles such that image shear is kept to a minimum. Solutions that use input from other onboard sensors, such as inertial sensors, will also be considered.

PHASE I: Develop a preliminary design for a compact passive millimeter wave sensor and/or perform proof-of-concept lab and/or field experiments to assess the feasibility of the proposed approach; should show promise for providing sufficient information to aid a nav system onboard an aerial vehicle flying over a variety of landscapes at an altitude on the order of 100 to 3000 meters in rain and/or fog.

PHASE II: Develop and fabricate a compact passive millimeter wave sensor and demonstrate that the system can be used to aid a navigation system on a moving platform, without GPS, in rain and/or fog.

PHASE III: Refine the design from Phase II, develop a system prototype for use in a captive carry flight test or onboard an unmanned aerial vehicle, and commercialize the technology.

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KEYWORDS: passive millimeter wave, GPS denied navigation, simultaneous localization, mapping, feature-based navigation

AF15-AT27 TITLE: Exploitation Algorithms in the Compressive Sensing (Sparse Measurement) Space

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop algorithm and processing techniques to permit target detection and classification for weapon seekers to be performed directly in the compressed sensing domain, rather than in the reconstructed data domain.

DESCRIPTION: There is a tremendous amount of research being performed in areas related to compressive sensing (compressive sampling). This research centers on the development of techniques that allow sparse or compressible signals (not strictly images) to be reconstructed from samples taken at rates significantly below the Nyquist rate. A particularly interesting application of this theory is the development of single-pixel cameras from which a fairly highly resolved image can be reconstructed, as well as low-resolution cameras from which significantly higher resolution images can be recreated. A motivating factor for this prior work has been the realization that in most imaging sensors, huge focal plane arrays are used to acquire the raw image, but the raw data is immediately subjected to compression algorithms that essentially "throw" away a large quantity of the collected data (e.g., JPEG compression) with minimal impact on the information content of the image. The thought behind the application of compressive sensing is that rather than using a sensor system that requires high-rate sampling followed by extreme data compression, simply develop a sensor system that initially makes low-rate measurements directly in the compressive domain. Under the compressive sensing theory, it is possible to show that under some reasonable assumptions about the sensed signal and the selection of a measurement matrix that satisfies certain reasonable conditions, a signal can be perfectly reconstructed with sparse (well below Nyquist) sampling. A natural progression from the realization that a signal can be reconstructed from these sparse measurements is the realization that it should be possible to perform processing operations on the equivalent representation of the sensor data in the low-dimensional sparse domain directly rather than first having to reconstruct the signal. Obviously, if the signal can be reconstructed from the sparse measurements all the information available from a reconstructed signal must be present in the sparse measurement domain. Therefore, it should be possible to perform processing and reasoning techniques directly in the measurement domain without going to the expense of signal reconstruction. This possibility is particularly attractive in applications (like machine learning and computer vision) where there is no real need to recreate the signal if the required processing can be accomplished directly in the sparse domain. There would be at least two advantages to being able to perform signal processing directly in the sparse measurement domain. The most obvious advantage being elimination of the costs (resources/time) to reconstruct the signal. A second advantage may be a reduction in the raw computational throughput required that results from the significant reduction in the sheer quantity of the raw data (i.e., data quantity commensurate with the sparsity of the measurement space). A particular application for this conjectured capability is in weapon seeker design for an autonomous weapon. Being able to collect data in a sparse measurement space and perform the required target detection and classification tasks directly in the space would theoretically reduce the sensor H/W complexity as well as the processing throughput requirements - thereby significantly reducing the seeker cost. Of particular interest is the development of this technology for air-to-ground weapon applications (primarily electro-optical imaging sensors or RF sensors) where background clutter complicates the detection and classification of targets.

PHASE I: Phase I objectives will be to extend the theory of compressive sensing (CS) to identify methods to conduct target detection and classification directly in the compressive measurement (sparse) domain without reconstructing the signal. Work in this phase should include a CS simulation to develop simulated sparse measurement data and development of prototype detection/classification algorithms.

PHASE II: Phase II objectives will be to continue developing and refining target detection and classification algorithms that operate in the sparse measurement space and the fabrication of a CS sensor and processing H/W to demonstrate the algorithms operating on compressively measured sparse data. The CS sensor can be a new fabrication or an existing CS sensor. A system demonstration consisting of a ground test showing algorithm operation on realistic targets in realistic environments is envisioned.

PHASE III: Phase III will require a design and fabrication of a compressive sensor for a realistic flight demonstration. Collect compressed measurement data using the developed sensor and demonstrate target detection/classification algorithms operating on the flight data.

REFERENCES:
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KEYWORDS: compressive, sensing, compressed, sampling, sparse, detection, classification, representation

AF15-AT28 TITLE: Development of a Multi-scale Simulation Framework to Study the Response of Energetic Materials to Transient Loading

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Software package for modeling and simulation of a condensed phase explosive with a heterogeneous meso-structure to imposed loads. This will connect the physics at the meso-scale with overall macro-scale response of the energetic material.

DESCRIPTION: Meso-scale simulations are frequently regarded as ones where the mesh or material description is resolved down to the level where individual constituents are treated with separate continuum level material descriptions. For the case of a traditional energetic material, this would imply resolving the description down to the constituent materials including the energetic crystals, voids, and any added inert materials. On the other hand, at the macro-scale the explosive can be viewed as homogeneous but with an overall behavior that is described by some homogenization of the physics at much smaller scales, i.e., the meso scale. Of course, descriptions at the atomic scale could be considered, but this topic is primarily aimed at phenomena where the constituent materials are modeled at the continuum level. However, methods that incorporate molecular dynamics to the meso scale will be considered if they address specific problems. One such area could be the modeling of the crystal matrix debonding where molecular dynamics are used to describe the strength of the bond between constituent materials and the matrix fill. Accurately handling the material-to-material interface of individual constituents is seen as a critical portion on the problem. Debonding between the binder and other constituents can play a major role in the formation of hot spots even for loads well below the shock regime. Innovative interface treatment techniques, such as level sets, developed to give accurate behavior while maintaining computational efficiency is highly desired. In modeling the response of the overall energetic material, particularly in the initiation phase of the explosive, it is important to capture and represent phenomena that occur at the meso scale, such as crystal to crystal interaction, crystal and matrix debonding and the collapse of voids. This will require a multi-scale modeling capability that will connect the meso-scale physics to the macro-scale behavior. Innovative techniques that can bridge the scales in a single simulation can be considered. Consideration should be given to collecting volumetric data to aid in the evaluation of areas where thermally driven chemical reaction may occur, i.e., hot spot formation and possible statistical analysis of hot spot distribution leading to chemical reaction. Another key is the ability to computationally develop and evolve damage at the meso scale such as cracking occurring from crystal to crystal interactions. The ability to link damage to changes in energetic sensitivity is highly desired.

PHASE I: Demonstrate the ability of the computational code to simulate the shock dynamics of a meso-scale sample and extract appropriate information from the simulations that can be used in a macro-scale multiphase mixture model of the energetic material. Accurate means of treating material-to-material interfaces should be demonstrated.

PHASE II: Develop the capabilities to take both imaged and idealized (engineered) meso-structures for an energetic material and compute the mechanics of such microstructures in 3-D. Extend the techniques for bridging scales demonstrated in Phase I to perform simulations of a typical energetic material up to and including system scale simulations of the transition to detonation of the energetic material. The techniques developed should be applicable to a broad range of energetic or reactive materials.

PHASE III: This technology is applicable to materials other than energetics such as fiber composites and concrete. Multi-scale modeling techniques will be important in better designing devices and structures. It will enable the study of response of a wide class of heterogeneous materials to shock.

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4. Baer, M.E., Mesoscale modeling of shocks in heterogeneous reactive materials, in Shockwave science and technology reference library. 2007, Springer Berlin Heidelberg. p. 321-356.

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KEYWORDS: multiscale modeling, energetic materials, explosives, computational modeling and simulation, mesoscale

AF15-AT29 TITLE: Biomimetic Material Solutions for the Stabilization of Labile Reagents

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop biocompatible material and processing solutions to enhance the stability of labile reagents (enzymes, drugs, vaccines) in austere environments.

DESCRIPTION: Material solutions are needed to eliminate or reduce the reliance on temperature control systems in the supply chain by replacing, modifying or stabilizing reagents and other heat sensitive items. The project focus is to develop bio-compatible materials that would entrap and stabilize labile reagents for remote use, with an emphasis on compact form and ease of deployment. Reagents could include temperature-sensitive biologics, ranging from vaccines, antibiotics and antibodies, to non-protein therapeutics such as small molecules, neutraceuticals and related compounds. The materials for stabilization of reagents should be FDA-approved or generally recognized as safe (GRAS). Formats could be contained in pre-formed packaging or so-called "blister packs" to be readily consumed by personnel deployed in the field or austere environments. The ease of consumable use should be at least comparable to conventional methods. Applications that address all product needs from stabilization results from proof of concept to manufacturing will be deemed as having highest priority. The technology should ultimately have the potential to be scalable for mass production and stock piling for long-term usage.

PHASE I: Proof-of-concept studies to explore new material technologies for field usage demonstrating stabilization of reagents at elevated temperatures (> 40 degrees C) for prolonged time periods (about six months) without cold storage. Studies demonstrating efficacy under relevant conditions should be demonstrated. For example, for enzymes or proteins, functional assays must be performed for activity.

PHASE II: Scale-up feasibility and good manufacturing practices issues must be addressed. Bioavailability and relevant properties compared to control reagents using appropriate model system. The quality control parameters and decreases in product variability should be addressed. It is expected that the research conducted will enhance the availability of stabilized molecules for a variety of deployed/operational needs in the context of resource-limited settings.

PHASE III: Military application: Stabilization of biological reagents and extending shelf-life of bio-reagents for combat care and point-of-care diagnostics. Commercial application: Materials to stabilize biologics for use in remote location (with cold chain logistics) for treatment and prevention of diseases.

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2. Zhang et al. (2012) Stabilization of vaccines and antibiotics in silk and eliminating the cold chain. PNAS 109, 11981-11986.

KEYWORDS: biomimetics, biomaterials, cold chain, encapsulation

AF15-AT30 TITLE: Rapid Deployment of Thermodynamic Capability for Integrated Computational Materials Engineering

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Significantly accelerate the development, deployment and accuracy of thermodynamic and kinetic databases used in the Integrated Computational Materials Engineering processes.

DESCRIPTION: Recently, the Air Force Research Laboratory's Materials & Manufacturing Directorate has proposed using Integrated Computational Materials Engineering (ICME) to significantly reduce the time to develop and deploy new materials [1]. One technology that can markedly impact this problem is the Calculation of Phase Diagrams (CALPHAD) method [2]. These are thermodynamic models for making quantitative predictions of phase equilibria, volume fraction, solidification paths, and other thermodynamic quantities of engineering materials. Currently, hypothetical questions involving systems with 10-plus components can be answered about metallic systems from desktop CALPHAD software systems. Such results provide the fundamental underpinnings of evolutionary and revolutionary materials development. Expanding the reach of these tools would accelerate materials development and implementation across the transportation and energy generation (turbine engine) communities. The main sources of error in these methods are the availability and accuracy of multi-component databases, the physical and numerical representation of the thermodynamic quantities and the stability of the multivariate solvers. Developing these databases is costly and time consuming and the underlying structure representing this data in the CALPHAD methods is inflexible, requiring significant hard coding to incorporate new or improved experimental data. Significantly advancing the CALPHAD methods requires changes in the structure and extensibility of the databases which would lead to a natural, community-driven evolution of the underlying data. Advances in these methods should also include Bayesian, or its equivalent, methods for managing and reducing the intrinsic errors in the predicted properties. Further, the methods should provide feedback to the user based on what experimental data (phases, chemistry and temperature) are needed to improve the accuracy of the approach for a particular problem. Finally, rapid, parallel and robust experimental-testing techniques need to be developed to provide the breadth of thermodynamic data needed for these databases. In order to reach the stated ICME goal of a 50 percent reduction in time and cost, proposals are sought for developing technologies that produce rapid and accurate thermodynamic predictions through (but not limited to): accelerated development of thermodynamic databases, new easily extensible databases, more accurate thermodynamic models [3], advanced application of multivariate solvers, Bayesian methods for improving precision and feedback to the user on the optimum pathway for improving the databases for a specific application.

PHASE I: Demonstrate the efficacy of new, more accurate thermodynamic models, automated thermodynamic reassessment methods, or rapid experimental methods for measuring thermodynamic reference point. Also, provide a metric for the time reduction achieved with the extension or modification of these tools.

PHASE II: Demonstrate a method for predicting multi-component (>8) thermodynamic quantities for a new alloy system. Demonstration would include error assessment of output (phases diagram, solidification paths, etc.) and feedback to the user for what experimental data is needed to improve precision of method.

PHASE III: Commercialize advances into CALPHAD method or equivalent for application to current & next-generation high-temperature structural alloys. This will include, but not be limited to, Ni-based superalloys, Ti alloys and new alloys systems, including chemically complex alloys (i.e., high entropy alloys).

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2. N. Saunders and P. Miodownik, Calphad, Pergamon Materials Series, Vol 1 Ed. R W Cahn (1998).

3. See for example: "Application of the cluster/site approximation to the calculation of multicomponent alloy phase diagrams," W. Cao. Y.A. Chang, J. Zhu, S. Chen, and W.A. Oates, Acta Materialia, 53 (2005), 331-335.

KEYWORDS: ICME, thermodynamics, phase diagram, alloy development

AF15-AT31 TITLE: Environmentally-Compliant Inorganic Material(s) for Corrosion and/or Wear Protection of Structural Metals on Military Aircraft and Weapon Systems

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Environmentally-compliant inorganic material(s) for corrosion and/or wear protection of structural metals on military aircraft and weapon systems.

DESCRIPTION: This effort will identify one or more novel and unique inorganic material(s) for corrosion and/or wear protection of structural metals. The new material systems will eventually replace environmentally hazardous inorganic materials, in particular heavy metals, currently used in the fabrication, maintenance, and/or sustainment of military aircraft and weapon systems hardware. Innovative and novel materials are sought. The new material(s) can be homogeneous single substances, or multi-component composites or alloys. The new material systems shall not employ any materials currently identified on the Office of the Secretary of Defense's (OSD) Emerging Contaminants WATCH List and/or ACTION List.[5] This program will not encompass the use of materials/material systems that are now commercially available. Additionally, the new material(s) must match or exceed the current materials' resistance to corrosion and/or wear resistance in the targeted use/application. While most corrosion and wear-resistance requirements are system specific, the replacement material(s) will need to meet minimal requirements for white and red rust corrosion resistance. That resistance needs to be, in a 5% sodium chloride solution at 95 °F per the ASTM B117 Salt Fog Test, 96 hours resistance to white rust and 500 hours to red rust. Wear protection should not exceed 11.60 x 10^-6 cubic inches of lost material as per ASTM G115, unless the actual end-use specifies a different value.

All military aircraft and weapon systems have a long history and experience with the challenges of sustainment and repair operations in an ever-evolving and increasingly demanding environment, safety, and occupational health (ESOH) environment on the use of toxic inorganic materials [1-4]. Furthermore, many military depots and repair facilities have faced recent and significant OSHA non-compliance violations due to exposures to toxic and/or carcinogenic heavy metals, such as Chromium VI and cadmium. Restrictions by the U.S. government, international organizations, OSD, and/or the Air Force, on toxic chemicals and hazardous processes are continually becoming more stringent going forward [2-4]. Targeted chemicals include, but are not limited to, heavy metals such as chromium (Cr), cadmium (Cd), beryllium (Be), nickel (Ni), and cobalt (Co). The depot industrial processes that use or are affected by these toxins are critical to the military's mission effectiveness. As such, the Air Force Sustainment Center compiled a list of the Air Force's needs, including environmentally benign alternatives for: (1) coatings on high strength steel; (2) coatings for inner diameters of cylinders/tubes; (3) coating replacements on high-strength steel; and (4) materials for landing gear bushing/bearing applications. Those proposals that address one or more of the above listed applications will be preferred.

While no single material/composite/alloy is likely to replace all the present applications, preference will be given to those material systems that will have the broadest applications within the military/Department of Defense with those applications listed above.

PHASE I: Formulate and perform laboratory testing of one or more inorganic material(s) substances, as described above. Provide experimental evidence to show that the candidate(s) will meet the performance characteristics of corrosion resistance and/or wear resistance, as well as life cycle costs, if used on military aircraft and platforms.

PHASE II: Down select one or more materials from the Phase I effort. Further develop it/them into a usable product for proof-of-concept demonstration program. The new material system(s) will be applied to actual military aircraft and/or platforms for actual demonstration, and will include monitoring of the system(s) in the field by inspections and maintenance.

PHASE III: Military & Commercial Applications: The new environmentally safer, inorganic material system(s) will provide equivalent and/or improved corrosion protection/resistance and wear resistance while improving worker safety and better complying with the ever-increasing environmental regulations.

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4. Denix – DoD Environmental, Safety, and Occupational Health Network and Information Exchange, http://www.denix.ods.mil/cmrmd.

5. OSD's Emerging Contaminant ACTION and WATCH Lists.

KEYWORDS: Environmentally friendly, environmentally benign, environmentally compliant, greener, corrosion, corrosion resistant, wear resistance, wear protection, inorganic materials, inorganic metal composites, metal alloys, aircraft, military platforms, chromium replacement, cadmium replacement, hazardous material replacement

AF15-AT33 TITLE: High Speed Electronic Device Simulator

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop and demonstrate a software package based on Fermi kinetics charge transport and Delaunay/Voronoi field discretization that accurately predicts semiconductor device behavior from dc up through the mm-wave and THz frequency ranges.

DESCRIPTION: Wireless communications, radar, imaging, spectroscopy, and chem/bio detection require electronic components operating in the mm-wave and THz frequency ranges. While GaAs metal semiconductor field effect transistor (MESFET) and nanoscale CMOS technologies have demonstrated high frequency capabilities, these applications will likely require additional material systems and device architectures such as InP HBTs, GaN HEMTs, or possibly gated graphene structures. The cost of exploring this wide design space can be reduced with predictive, physics-based simulation capabilities.

Predictive high-speed device simulation requires hot electron transport with electronic band structure and explicit electron scattering. The transport model should also be numerically efficient, couple readily to electromagnetic (EM) fields, and accommodate both fast and slow physical processes.

High frequency simulation also requires full wave EM. In the THz range, field fluctuations are comparable to the electron momentum relaxation rate [1], causing the device to transition from nonlinear active to linear passive behavior. Propagation delays and inductive coupling can also be apparent at even lower frequencies, below 70 GHz [2]. These effects require full wave EM, i.e., including Ampere's and Faraday's laws among the device equations.

One hot electron model is ensemble Monte Carlo (EMC). This method stochastically tracks mobile charges as they drift in EM fields and scatter randomly in momentum space. With electronic band structure, it can be highly accurate. However, the stochastic algorithm has difficulty treating both fast and slow processes. Moreover, EMC is very computer intensive, particularly with full wave EM.

Energy transport models, such as hydrodynamics, are more numerically efficient. However, they typically exhibit numerical instabilities, and accuracy requires fitting parameters, such as field-dependent mobility.

Full wave EM for semiconductor devices is generally treated with the finite difference time domain (FDTD) method. It is conceptually simple and can represent divergence and curl operators in a consistent way. However, it requires a structured mesh and decouples the field and charge dynamics in time, such that they are never solved simultaneously. Stability issues often require highly absorbent perfectly matched layer boundary conditions when FDTD is coupled to nonlinear charge transport.

This project concerns simulation different in both the transport and EM components. Mobile charges are treated with Fermi kinetics transport (FKT), an energy transport model based on thermal physics of ideal Fermi gases. It includes the thermodynamic identity to enforce the 2nd law of thermodynamics throughout the simulation domain [3]. It is robust and flexible enough to accommodate full electronic band structure and explicitly include charge scattering. It is also highly accurate, capturing important hot electron effects, such as velocity overshoot, with accuracy comparable to EMC but at a small fraction of the computational cost [4].

The dynamic field component of this simulation is discretized with the Delaunay/Voronoi surface integration (DVSI) method [5]. It is an extension of the box integration method, which uses an unstructured primary mesh and its Voronoi dual to represent the divergence operators in Gauss's law and charge conservation. Assigning rotational fields to primary and dual edges and applying the Stokes theorem approximates the curl operators in Ampere's and Faraday's laws in a manner compatible with the box integration method's divergence operators. This spatial discretization combined with implicit time stepping allows the simultaneous solution of both the field and charge dynamics. The results are dc and high frequency device simulations that agree well with measured data without relying on fitting parameters.

PHASE I: A simulation framework producing a device geometry, generating a Delaunay mesh, and displaying results should be demonstrated. In this framework, the FKT model should then be implemented with parabolic band structure. It should also be coupled to full wave EM using the DVSI discretization scheme to demonstrate the fully self-consistent solution of high frequency field and charge dynamics.

PHASE II: This phase incorporates electronic band structure and scattering mechanisms. It involves computing quantities required for FKT from band structure isosurfaces as described in [5]. The resulting simulator should be verified through comparisons with measured data, such as drift velocity versus electric field for technologically important semiconductors (e.g., Si, GaAs, GaN) as well as the dc and high frequency characteristics of active device structures (e.g., MOSFET, MESFET, HEMT).

PHASE III: This phase optimizes the simulator to maximize speed and minimize memory. It should also produce a commercially viable simulator with user-friendly graphical interface, robust solid modeler and mesh generator, as well as post-processing utilities.

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KEYWORDS: high speed electronics, computer simulation, charge transport, electromagnetics

AF15-AT34 TITLE: Enabling Moving Target Hand-off in GPS-Denied Environments

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a capability for enabling hand-off of moving targets between multiple assets in a GPS-denied environment.

DESCRIPTION: When operating in a denied environment, it may be advantageous to have multiple, small assets collecting ISR rather than a single, larger platform. However, when using multiple assets, the handoff problem must be solved, meaning that when one platform is tracking an object of interest, the responsibility for tracking that object must be able to transition to another platform. Currently, this handoff is reliant on Global Positioning System (GPS), whether using location estimates of the moving target to determine whether two platforms are looking at the same target [1], or just using location estimates to know where two sensors should look to use appearance-based handoff. In either case, the problem will become far more difficult in a denied environment when GPS is not available.

For this topic, an approach for enabling handoff of a target between multiple agents without GPS should be developed and demonstrated. This system should work whether handoff is between two sensors of the same modality (e.g., two color, electro-optical cameras) or of different modalities. For the purpose of this project, minimizing communication is not a high priority, but communication requirements should be realizable with current, low-cost systems (e.g., WiFi systems, or 1-2 Mbits/s communication channels.) Two significant components of a system that solves this problem will include:
(1) Distributed computation of relative pose estimates. The pose (location and attitude) estimation routine should be decentralized and capable of using ranging and/or bearing measurements between agents to determine relative pose estimates. Magnetometers or similar sensors that provide some global information can be assumed, but systems providing global location estimates (GPS, LORAN, etc.) cannot be assumed. The algorithms developed should be scalable to very large numbers of agents.
(2) Algorithms for ensuring proper handoff between agents. While appearance-based approaches can be used to "finalize" a handoff, the problem of jointly deciding where to point a sensor that is not currently tracking an object to start the handoff process will need to be solved prior to appearance-based methods becoming applicable. In addition, for multiple modality cases, relative-pose based methods may be all that is available to enable handoff. Once the sensors are pointing at the same general area, deciding when a particular object has been identified by both agents must be done in a probabilistically reasonable fashion.

Effectiveness of proposed approaches will be evaluated on how accurately relative pose can be computed in a distributed fashion. In particular, the impact of relative pose errors on the probability of two sensors identifying the same target will need to be characterized. In Phase I, this can be done using a simulation environment developed by the contractor. Closed-form expressions for in-accuracies introduced by the relative-pose uncertainties can be validated by these simulations. In Phase II, the goal will be to demonstrate handoff working between two or more small unmanned aerial vehicles (UAVs) flown by the government.

PHASE I: The algorithm design of a system enabling handoff without GPS should be performed using simulation of realistic scenarios. For Phase I, a more limited scenario can be considered. For example, handoff can only be required between similar modality sensors, estimation can be performed on a centralized computation platform, etc.

PHASE II: Extension of the algorithms designed in Phase I to more difficult scenarios should be achieved. Demonstration of a fully decentralized, method for enabling handoff in a GPS-denied environment for both same modality and multi-modality systems should be the goal of this phase.

PHASE III: Further development for target customers to enable either military or civilian applications. Civilian applications could include urban search and rescue, security tracking, and team-based robotic sporting events (i.e., robocub).

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KEYWORDS: moving target tracking, distributed estimation, GPS-denied navigation, relative navigation, multi-agent estimation and control

AF15-AT35 TITLE: Small Sample Size Semi-Supervised Feature Clustering for Detection and Classification of Objects and Activities in Still and Motion Multi-spectral Imagery

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop semi-supervised feature clustering technology that can improve detection and classification of objects and activities in still and motion imagery based on a small labeled training set in a high-dimensional feature space.

DESCRIPTION: In a typical exploitation scenario analysts are able to collect only a small number of confirmed samples of objects of interest. This is caused by the specifics of military scenarios and by the fact that analysts spend about 80% of their time looking for the right data and only 20% analyzing the data. There is a need for machine learning methods that can assist the analysts in identifying additional candidates in unlabeled data for manual verification.

Image processing algorithms extract large number of possibly redundant features which decrease classification accuracy and increase computational time. Reducing the number of features therefore is an important preprocessing step in machine learning. Feature extraction algorithms, such as PCA, LDA, and CCA, map the original feature space to a new feature space where the features are difficult to interpret. Feature selection algorithms preserve the original features and thus provide superior interpretability. These algorithms are, however, inefficient as their computational complexity is exponential in the number of features. Feature clustering methods reduce dimensionality while attempting to fully represent information important for classification and thus are a promising direction for efficiency and interpretability. Conventional feature clustering techniques perform poorly in the scenarios with small number of labeled samples. When number of training samples is small, the solution is to take into account unlabeled data, which is the case of semi-supervised feature selection. The objective functions utilized in feature clustering optimize the quality of clusters and are not directly related to the classification criterion.

The goal of this topic is to develop semi-supervised feature clustering methods when only a small number of positive training objects is available along with a large amount of unlabeled data. The feature clustering algorithms should optimize a criterion related to the classification problem. The developed algorithms should have computational complexity that is not exponential in the number of features.

The desired machine learning algorithm will have available a small number of objects of interest, one object as the limiting case, and a large amount of unlabeled data that may or may not contain objects similar to the object of interest. The object and feature extraction algorithms will produce object description with a large number of features. The goal of the learning algorithm is to simultaneously identify objects that are similar to the training sample and to select features that optimize the similarity measure. The proposed methodology has to be compared to state of the art machine learning techniques and validated on electro-optical data such as MAMI-I data set recently collected by AFRL, CLIF dataset (EO/IR), ARCHER dataset (HSI) and possibly other similar datasets that are publically available.

The desired technology should include algorithms for object detection and feature construction in multi-spectral still and motion imagery. These algorithms may rely on knowledge of generic detection and classification problems in imagery and on the provided training samples.

This technology will have applications in both military and commercial domains. In the area of C4ISR the technology will be incorporated into the systems that help warfighters process more information with greater efficiency, for example in the counter-insurgency and counter-IED area. In the commercial sector this technology is applicable to situations with amounts of data that need to be analyzed exceeding the capabilities of personnel and only a few examples of targets being sought are available.

PHASE I: Propose novel semi-supervised machine learning technologies which can operate on training data containing large amounts of unlabeled data and a few (one in the limiting case) examples of targets of interest. Conduct preliminary tests using simulated data and real world imagery. Generate final report including the description of new technology, performance metrics and plans for Phase II.

PHASE II: Develop a prototype software system incorporating the technology in Phase I and apply it to detection of activities in sensor data and management of sensor networks. Apply developed technology to forensic datasets from radar, EOIR, WAMI, and HSI sensors. Demonstrate detection and false alarm performance. Demonstrate near real time performance. The deliverables include working prototype of the technology, specifications for its development, and performance evaluation with real-world data.

PHASE III: As a potential military application, transition to PCPAD-X. A potential commercial application for geographic Information system (GIS) data analysis could be developed. Integration with distributed common ground system (DCGS) can be considered.

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KEYWORDS: machine learning, feature selection, feature clustering, small sample size, layered sensing, EO/IR, activity detection, situational awareness, semi-supervised learning

AF15-AT38 TITLE: Diagnostics and Test Techniques for Complex Multiphysics Phenomena in Hypersonic Environments

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop improved techniques for non-intrusive sensing of key phenomena during ground and flight testing of integrated hypersonic flight systems.

DESCRIPTION: The Air Force is interested in hypersonic (M>5) systems that enable time-critical missions for strike and Intelligence, Surveillance, Reconnaissance (ISR). Perhaps more so than for any other flight regime, precise and accurate sensing of key phenomena is difficult without contaminating the data being collected. For example, aerodynamic data probes severely distort the down-stream airflow, greatly diminishing the utility of traditional wind tunnel force and moment measurement systems. A further complicating factor is that aerodynamic, propulsion, and structural parameters are closely intertwined for hypersonic systems. Therefore, the hole that is cut into a hot, thin structure (e.g., a wing) for a skin friction sensor will tangibly alter the aerothermal, mechanical, and acoustic response of the structure, and it will alter the response of the near-field air stream to the structural surface characteristics.

However, validation of hypersonic technologies and flight system designs requires high-resolution measurement devices and methods that can obtain the level of detail necessary to validate high-fidelity computational tools. Additionally, methods to process and combine information among the measurements often create a bottleneck in the validation process. The hypersonic research community requires advanced diagnostic techniques that extend the state of the art beyond the most advanced current methods.

This effort will develop and demonstrate advanced diagnostic devices and test techniques to precisely and accurately sense the effects of loads caused by aerodynamic, aerothermodynamic, aeroheating, propulsion, propulsion heating, mechanical, and acoustic processes. The devices and methods will be shown to perform non-intrusive sensing of far-field, near-field, surface, and subsurface phenomena for the following purposes:

• To characterize the three-dimensional pressure, temperature, and velocity field; from the surface to the far field; over a dimensionally large space on the order of one to ten feet in depth, width, and height at steady-state and transient conditions; with fine resolution to discriminate boundary layers and shock waves
• To precisely and accurately measure structural deformation; on the order of tenths and even hundredths of an inch; at and below the aerodynamic surface; at kilohertz sampling rates

The devices and methods will be developed for configurations of interest that represent complex hypersonic vehicles, incorporating the following features:

• Thin structures with strong temperature gradients and multiple material types
• Boundary-layer transition over large longitudinal and lateral spans as well and varying time spans
• Wing-body, wing-tail, and body-tail intersections
• Airframe-integrated mixed-compression and internal-compression inlets

Solutions of interest include, but are not limited to:

• Optical spectroscopy and fluorescence of non-reacting and reacting air and combustion flows
• Full field digital image correlation
• Laser-sensed displacement of discrete points and distributed points

PHASE I: Define specific phenomena to be measured, from the following domains: mechanical/thermal loads and deflections, shock wave-boundary layer interactions, interference effects from complex shapes. Establish goals for response range, sampling frequency, operating conditions, and measurement uncertainty. Document technology gaps that prevent development of more effective solutions.

PHASE II: Fabricate and test candidate diagnostic devices in bench-scale and laboratory-scale experimental facilities. Implement data analysis techniques. Demonstrate a proof-of-concept capability on one or more selected unit-scale experiments that incorporate the Phase I domains.

PHASE III: Apply selected devices and techniques to research experiments at major test facilities, with complex air vehicle geometries that incorporate the Phase I domains.

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KEYWORDS: hypersonic, hypervelocity, diagnostic, instrumentation, data analysis

AF15-AT39 TITLE: <u>Power Generation for Long Duration Hypersonic Platforms</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: This objective is to develop novel power generation solutions for long duration hypersonic applications. The electrical power required will be at least 1 MW for 30 to 60 minutes at flight speeds of Mach 5 to 6, at altitudes above 50 kft.

DESCRIPTION: This topic pursues novel solutions for power generation for long duration hypersonic applications. It is anticipated that the electrical power required will be at least 1 MW for 30 to 60 minutes at flight speeds of Mach 5 to Mach 6, at altitudes above 50 kft. Envisioned combined cycle engine systems will not have a rotating core to drive a gearbox at speeds beyond Mach 3, thus, subsystems that are traditionally mechanically powered through a gearbox must be driven electrically, either directly through motor drives, or indirectly through an electrically pumped/pressured hydraulic accumulator. Because these platforms are not expected to have rotating core propulsion engines at hypersonic speeds, prime electrical power generation could be driven by very high temperature ram or bleed air, derived from an environmentally-friendly expendable monopropellant, or possibly even harvested heat or flow energy using a thermoelectric, thermionic, or magnetohydrodynamic conversion process. Other power generation processes will be considered if able meet the requirements. With the high power level and long duration required, stored energy in the form of batteries is not expected to be a solution path unless combined with other power generation systems. Power generation solutions that also provide significant cooling/heat sinking for mission systems are desired if feasible.

Over the past 50 years, there have been several aircraft flown in similar altitudes and high speed ranges of interest, but there are significant differences for the envisioned hypersonic platform due to the use of air-breathing propulsion rather than rocket propulsion. Possibly the most successful of these rocket-based platforms was the circa 1960’s X-15, with demonstrated speeds in excess of Mach 6 and altitudes greater than 200 kft. (1) The two auxiliary power units on this aircraft used the same monopropellant as the rocket engines, hydrogen peroxide, to drive the electrical generators and hydraulic pumps; and liquid nitrogen to cool the cabin, electronics, and APU bearings. (1),(2) Similarly, the Space Shuttle also used three monopropellant auxiliary power units (APUs), but used hydrazine, for mechanical power for the hydraulic systems as well as electrical power generation. Each Shuttle APU was a 400 shaft-hp turbomachine that, through a gearbox, powered two hydraulic pumps and an alternator. Each turbine could provide 5,000 Btu/min of cooling heat sink for the hydraulic system. There were also three water spray cooling systems for the pumps and turbomachines. (3),(4) Aside from the main engines, the highest-risk equipment on the Space Shuttle were the APUs; and there was a strong desire to replace these with batteries and motors for improved safety and reliability. (5)

PHASE I: Perform trade study, including aircraft integration impacts to identify best power generation technology. Design a power generation system, and define the critical functions to be demonstrated in Phase II. Develop a transition plan and business case analysis. Document technology gaps that prevent development of more effective solutions.

PHASE II: Demonstrate the critical functions defined in Phase I. Establish a risk reduction plan to the development of full-scale subsystem hardware capable of operating at full temperature range and altitude requirements.

PHASE III: Develop partnerships with industrial firms to employ power generation technology to aircraft and other energy-dependent systems.

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KEYWORDS: power generation, turbomachine, auxiliary power unit, hypersonic

AF15-AT40 TITLE: <u>Impact of Hypersonic Flight Environment on Electro-Optic/Infrared (EO/IR) Sensors</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Investigate the impact of flow environment of hypersonic flights on electro-optic/infrared (EO/IR) sensors, and hence develop strategies to mitigate the adverse effects caused by the environment.

DESCRIPTION: Sensors are important for the success of hypersonic missions. EO/IR sensors can provide high spatial resolution images using multiband of frequencies ranging from the visible to mid-wave IR. EO/IR sensors have been very successful for terrain imaging from subsonic aircraft. However, the study of such sensors on-board hypersonic platforms has not been carried out in any detail thus far. There are several new challenges for EO/IR sensing that hypersonic vehicles present. Hypersonic flights produce a shock layer where part of the kinetic energy is transformed to heat. This then leads to hot flow, heated airframes and sensor bay windows. For instance, the outside temperature of sensor windows can be as high as 1000 degrees C. This condition places serious limits on the signal-to-noise ratio that can be achieved by the EO/IR sensors. For satisfactory operation of onboard sensors the sensor bay has to be maintained at 30 degrees C. Thus the window material has to perform satisfactorily even when it is subjected to such large temperature stress. Because of the need to image a large terrain strip the field of view of the EO/IR sensors has to be as large as 50 degrees. This requires a large size window. Note that a large window which meets all the requirements (withstand thermal stress, EO/IR transparency, physical strength, insulating capability, non-radiating) is hard to be found. Vibration and high-G maneuvers can considerably degrade high resolution imaging. Shock layer and boundary layer inhomogeneities can significantly refract and scatter EO/IR signals thereby degrading image quality. A good understanding of hypersonic air vehicles and aerothermodynamics is important for this project. Only then a realistic estimate of all the above mentioned effects is possible. Impact of the atmosphere on EO/IR signals is well known. However, in the context of sensing from hypersonic air vehicles, the atmosphere places another constraint on the selection of suitable frequency bands for EO/IR sensing. A simulation tool must be developed to assess these effects of hypersonic flight on EO/IR sensor performance. Also, strategies to mitigate the adverse effects should be provided.

PHASE I: Phase I will focus on the impact of hypersonic flow fields (Mach 5-7, altitude 25-30 km) on EO/IR sensors. The EO/IR system should cover a ground swath of around 50 km with NIIRS 7 resolution. Develop a framework for a simulation tool that captures pertinent design issues for EO/IR sensing from hypersonic platforms. Document technology gaps that prevent development of more effective solutions.

PHASE II: Complete the detailed study of the impact of hypersonic environment on EO/IR sensor performance. Include a reliable hypersonic flow field algorithm and finalize the simulation tool for EO/IR sensor design and performance study. Investigate and devise strategies to mitigate the adverse effects of hypersonic environments on EO/IR sensing. Document, deliver, and demonstrate the simulation tool, and mitigation strategies to AFRL for further evaluation at the end of Phase II.

PHASE III: Develop commercial tool for EO/IR sensor performance study. Government customers may include Air Force, Army, Navy, and NASA. Commercial interests may include sensor developers and system integrators for hypersonic air vehicles.

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KEYWORDS: EO/IR, hypersonics, hot flow environment, high speed air platform