# AIR FORCE
# 13.1 Small Business Innovation Research (SBIR)
# Proposal Submission Instructions

## INTRODUCTION

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.

The AF Program Manager is Mr. Augustine Vu, 1-800-222-0336. For general inquiries or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (1-866-SBIRHLP) (8:00 a.m. to 5:00 p.m. ET Monday through Friday). For technical questions about the topics during the pre-solicitation period (16 November 2012 through 16 December 2012), 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 (17 December 12 through 16 January 2013), go to http://www.dodsbir.net/sitis/.

General information related to the AF Small Business 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, www.aptacus.org/new/Govt_Contracting/index.php. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

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

## 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 so 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), and Company Commercialization Report).**

## 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 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 Sheets**: Proposal Cover Sheets: 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 Technical Volume. 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 Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm ET Monday through Friday).

**Key Personnel**: Identify in the Technical Proposal 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 purposes of DoD solicitations, individuals with dual citizenship, i.e., U.S. and another country, are not considered to be U.S. citizens.** 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 Volume 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**

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| **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 detail must be adequate to 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. Direct Cost 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 that cost share contracts do not allow fees. NOTE: Subcontract arrangements involving provision of Independent Research and Development (IRAD) 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 university or other consultants in the planning and/or research stages of the project may be appropriate. If the offeror intends such involvement, describe in detail and include information in the Cost Volume. The proposed total of all consultant fees, facility leases or usage fees, and other subcontract or purchase agreements may not exceed one-third of the total contract price or cost, unless otherwise approved in writing by the Contracting Officer. 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 Volume 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" within "Phase I Proposal Submission Checklist" section, p. AF-5).

j. DD Form 2345: For proposals submitted under ITAR-restricted Topics, a copy of the certified DD Form 2345, Militarily Critical Technical Data Agreement, 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/.

Note: Approval of the DD Form 2345 will be verified if proposal is chosen for award.

**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 Web site (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 Web site 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, 16 January 2013 deadline.** A hardcopy **will not** be accepted.

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. **If selected for award, the award contract or P.O. document received by your firm may vary in format/content from the model P.O. reviewed. 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.

The AF recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing 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 assure that your e-mail address listed in your proposal is current and accurate. By early July, you will receive an e-mail serving as our acknowledgement that we have received your proposal. The AF is not responsible for notifying companies that change their mailing address, their e-mail address, or company official after proposal submission without proper notification to the AF.

## AIR FORCE SBIR/STTR SITE

As a means of drawing greater attention to SBIR 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 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.

NOTICE: Only Government personnel and technical personnel from Federally Funded Research and Development Center (FFRDC), Mitre Corporation and Aerospace Corporation, working under contract to provide technical support to Air Force product centers (Electronic Systems Center and Space and Missiles Center respectively) may evaluate proposals. All FFRDC employees at the product centers have non-disclosure requirements as part of their contracts with the centers. In addition, AF support contractors may be used to administratively process or monitor contract performance and testing. Contractors receiving awards where support contractors will be utilized for performance monitoring may be required to execute separate non-disclosure agreements with the support contractors. See section "Cost Volume", item g regarding identification of Conflicts of Interest.

## On-Line 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.afsbirstr.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 and the notification process requires specific steps to be completed prior to a Contracting Officer distributing this information to small business.

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 e-mail 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.

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 should 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 Program Manager.** Organizations and their Topic Numbers are listed later in this section (before the Air Force Topic descriptions).

## PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology that was 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 contact information for technical/contracting points of contact has changed since submission of the Phase I proposal, contact the appropriate AF SBIR Program Manager, as found in the Phase I selection notification letter, for resolution. Please note that it is solely the responsibility of the Phase I awardee to contact this individual. 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](www.dodsbir.net/submission)**. The complete proposal – Department of Defense (DoD) Cover Sheet, entire Technical Volum with appendices, Cost Volume and the Company Commercialization Report – must be submitted by the date indicated in the invitation. The Technical Volume is **limited to 50 pages** (unless a different number is specified in the invitation). The Commercialization Report, any advocacy letters, SBIR Environment Safety and Occupational Health (ESOH) Questionnaire, and Cost Volume Itemized Listing (a-j) will not count against the 50 page limitation and should be placed as the last pages of the Technical Volume file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that 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 SBIR funds, up to a maximum of 750,000, to non-SBIR 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 Manager (see Air Force SBIR Organization Listing) for more information.

## AIR FORCE SBIR PROGRAM MANAGEMENT IMPROVEMENTS

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

## AIR FORCE SUBMISSION OF FINAL REPORTS

All Final Reports will be submitted to the awarding AF organization in accordance with the Contract. Companies **will not** submit Final Reports directly to the Defense Technical Information Center (DTIC).

| Topic Number | Activity | Program Manager |
|---|---|---|
| AF131-001 thru AF131-008<br>AF131-158 thru AF131-174 | Aerospace Systems Directorate<br>AFRL / RQOB<br>2130 Eighth Street, Bldg 45<br>Wright-Patterson AFB OH 45433 | Barbara Scenters<br>(937) 938-4708 |
| AF131-009 thru AF131-014 | Directed Energy Directorate<br>AFRL/RD<br>3550 Aberdeen Ave SE<br>Kirtland AFB NM 87117-5776 | Danielle Lythgoe<br>(505) 853-7947 |
| AF131-017 thru AF131-021<br>AF131-023 thru AF131-031 | 711th Human Performance Wing<br>AFRL/RH<br>2610 Seventh, St, Bldg 441<br>Wright-Patterson AFB OH 45433 | Sabrina Davis<br>(937) 255-3737 |
| AF131-033 thru AF131-034<br>AF131-036<br>AF131-038 thru AF131-039<br>AF131-041<br>AF131-044 thru AF131-052<br>AF131-054 thru AF131-055 | Information Directorate<br>AFRL/RI<br>26 Electronic Parkway<br>Rome NY 13441-4514 | Janis Norelli<br>(315) 330-3311 |
| AF131-057<br>AF131-060 thru AF131-083<br>AF131-092 thru AF131-095 | Space Vehicles Directorate<br>AFRL/RV<br>3550 Aberdeen Ave SE<br>Kirtland AFB, NM 87117-5776 | Danielle Lythgoe<br>(505) 853-7947 |
| AF131-098 thru AF131-099<br>AF131-101 thru AF131-105 | Munitions Directorate<br>AFRL/RW<br>101 West Eglin Blvd. Suite 143<br>Eglin AFB, FL 32542-6810 | Shirley Schmieder<br>(850) 882-3362 |
| AF121-108 thru AF131-116<br>AF131-118 thru AF131-124<br>AF131-126 | Materials & Mfg. Directorate<br>AFRL / RX<br>2977 Hobson Way, Rm 406<br>Wright-Patterson AFB OH 45433<br>Edwards AFB, CA 93524-7033 | Debbie Shaw<br>(937) 255-4839 |
| AF131-128 thru AF131-133<br>AF131-135 thru AF131-153 | Sensors Directorate<br>AFRL/RY<br>2241 Avionics Circle, Rm | Claudia Duncan<br>(937) 528-8510<br>Julie Harris |

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| | N2S24<br>Wright-Patterson AFB, OH 45433 | (937) 528-8515 |
| AF131-175 thruAF131-177 | 96th TW/XPXR<br>101 West D Avenue Bldg 1<br>Eglin AFB, FL 93524-6843 | Ramsey Sallman<br>(850) 883-0537 |
| AF131-180 thru AF131-182 | Arnold Engineering Development Center<br>AEDC/TSTY<br>1099 Schriever Ave Arnold AFB, TN 37389-9011 | William Mallory<br>(931) 454-7081 |
| AF131-185 thru AF131-189 | Air Force Flight Test Center<br>AFFTC/XPR<br>1 S. Rosamond Blvd,<br>Bldg 1, Rm 103A<br>Edwards AFB, CA 93524-6843 | Abe Attachbarian<br>(661) 277-5946 |
| AF131-190 thru AF131-193 | Oklahoma City Air Logistics Center<br>OC-ALC / ENSI<br>3001 Staff Drive, Suite 2AG70A<br>Tinker AFB, OK 73145-3040 | Edwin Kincaid<br>(405) 736-2577 |
| AF131-196 thru AF131-199 | Ogden Air Logistics Center<br>OO-ALC / LHH<br>6021 Gum Lane<br>Hill AFB, UT 84056-2721 | John Jusko<br>(801) 586-2090 |
| AF131-202 thru AF131-206 | Warner Robins Air Logistics Center<br>WR-ALC / ENSN<br>450 Third Street, Bldg. 323<br>Robins AFB, GA 31098-1654 | Frank Zahiri<br>(478) 327-4127 |

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| AF131-138 | Lightweight AEHF Modem for Manpack |
| AF131-139 | GMTI Data Exploitation for SWAP Limited Radar Systems |
| AF131-140 | Advanced Dual Band Apertures for improved early warning and space situational awareness missions |
| AF131-141 | Antenna Design for Unmanned Aerial Vehicles |
| AF131-142 | Packaging High Power Photodetectors for 100 MHz to 100 GHz RF Photonic Applications |
| AF131-143 | Computational Electromagnetics for a Systematic Security Evaluation and Countermeasure of Electromagnetic Analysis (EMA) on Electronic Security Devices |
| AF131-144 | Low Power Multi-Channel RF and Digital GPS Anti-Jam ASIC |
| AF131-145 | Light Weight High Gain High Data Rate Launch Vehicle Antenna |
| AF131-146 | Space based Hyper-Spectral Imaging Sensor |
| AF131-147 | Affordable Sub-array for TT&C Phased Array Antennas |
| AF131-148 | Low cost Diplexer for High performance phased array antenna |
| AF131-149 | GNSS Antenna Arrays for Situational Awareness |
| AF131-150 | Coherent Imaging Laser Source |
| AF131-151 | Speedy Sparse Bundle Adjustment for Video/Image Sequences |
| AF131-152 | Low Noise Photonic Oscillator in Short-Wave Infrared (SWIR) Band |
| AF131-153 | Precise Estimation of Geo-location Uncertainty |
| AF131-158 | Cetane Sensor for Remotely Piloted Aircraft (RPA) Propulsion Systems that Operate on Heavy Fuel |
| AF131-159 | Innovative Hybrid Power System for Increased Endurance Rapid Response Small Unmanned Aerial Systems (SUAS) |
| AF131-160 | Advanced Propulsion and Power Concepts for Large Size Class Unmanned Aerial Systems (UAS) |
| AF131-161 | Improved Reaction Models for Petroleum and Alternative JP-5/8 Fuels |
| AF131-162 | Improved Fidelity Predictions for Resonant Stress in Turbine Components |
| AF131-163 | Bearing Analytical Software Development and Validation |
| AF131-164 | Real-time Tactical Aircraft Fuel Ullage Oxygen Sensor System for Inerting Operations |
| AF131-165 | Aircraft Energy Management |
| AF131-166 | Scalable, Wide Bandgap Integrated Circuit Technology for Wide Temperature, Harsh Environment Applications |
| AF131-167 | Thermal Interface Materials for Power System Components |
| AF131-168 | Rotary Electromechanical Actuator for Next-Generation Thin-Wing Aircraft Flight Control |
| AF131-169 | Robust Cryogenic Compatible Turbo-machinery and Liquid Rocket Engine coatings |
| AF131-170 | Compact High Current Molecular Atomic Particle Beam Generator |
| AF131-171 | Hypersonic Propulsion: Enhancing Endothermic Fuel Technology |
| AF131-172 | Frequency Domain-based Electrical Accumulator Unit (EAU) |
| AF131-173 | Combustion Enhancement of Liquid Fuels via Nanoparticle Additions |
| AF131-174 | Enhanced Multi-wall High Pressure Turbine Blade Architecture |

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| AF131-175 | Micro Airborne Relay Technology |
| AF131-176 | Reusable Extended Artificial Light Source |
| AF131-177 | Angle of Incidence (AOI) Measurement Capability |
| AF131-180 | Directed Energy Wind Tunnel Test Methodology |
| AF131-181 | Computational Modeling of Coupled Acoustic and Combustion Phenomena Inherent to Gas Turbine Engines |
| AF131-182 | Non-Fluid Refrigeration Technology for Cooling Infrared Focal Planes and Other System Components below 50 K in Cryo-Vacuum Test Chambers |
| AF131-185 | Compact Multi-spectral Scene Projector Technology |
| AF131-188 | Gas Turbine Engine Particle Emission Characterization |
| AF131-189 | Wind Tunnel High Temperature Heater Element |
| AF131-190 | Dimensional Restoration of Aircraft Components Damaged by Corrosion |
| AF131-191 | Image Quality Indicator(s) and Software for Computed Radiography (CR) |
| AF131-192 | Corrosion Identification, Removal and Cleaning of Galvanic Couples in Difficult to Access Areas |
| AF131-193 | Composite Calibration Standards Kit for Calibration of Multiple Equipment in the AF Inventory Used for Composite Nondestructive Inspection (NDI) |
| AF131-196 | Landing Gear Strut Operational Readiness Monitoring |
| AF131-197 | Advanced OSHA Compliant Blast Cleaning Rooms (No Blast/HM Residue Migration Outside Blast Cleaning Room) |
| AF131-198 | Find substitute for Methylene Chloride in depaint operations at Hill AFB |
| AF131-199 | Blast Booth Noise Reduction - An OSHA Compliance Issue |
| AF131-202 | Surface Treatments for Stainless Steel Actuators |
| AF131-203 | High-Efficient Liquid Desiccant and Chloride Removal for Corrosion Mitigation and Control |
| AF131-204 | Aircraft Maintenance Management to Unanticipated Failure Events |
| AF131-206 | Networked Sensor Systems for Aircraft Maintenance |

# Air Force SBIR 13.1 Topic Descriptions

AF131-001 TITLE: Conformal Antenna Technology for Improved Signal Intelligence (SIGINT)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop and demonstrate conformal antenna concepts to enable tactical signal intelligence (SIGINT) for threat detection/avoidance and targeting for Special Operations AC/MC-130Js and similar legacy aircraft.

DESCRIPTION: Air Force warfighters are becoming increasingly interested in employing conformal antenna technology when adding new radio frequency (RF) sensing capability to fielded aircraft. Conformal antennas add minimal weight, have minimal aerodynamic drag, and also have no visual signature. Because conformal antennas impart minimal impact to the flight performance of aircraft, they offer the possibility to install a greater number of antennas, or larger antennas, which can enable increased sensor performance. A number of conformal antennas technologies are in development. Direct write is a technology that allows antennas to be sprayed on complex geometries such as aircraft skins. Structural excitation technology uses conductive aircraft skins to serve as the antenna. Other concepts feature antenna elements embedded in composite skin panels.

This effort is intended to demonstrate conformal antenna concepts that will enable tactical SIGINT exploitation of traditional and non-traditional signals of interest (NTSOI) for threat detection/avoidance and targeting for Special Operations AC/MC-130Js. NTSOI frequencies range from 10 MHz up to 6,000 MHz. Many NTSOI are vertically polarized. The C-130J has a length of 98 ft, wingspan of 132 feet, and a height of 39 ft. The aircraft has four turboprop engines and a service altitude of 28,000 ft. The aircraft features traditional built-up aluminum construction. The integration of conformal antennas with the conductive aluminum skins of the AC/MC-130Js presents a technical challenge and may require replacement of aluminum components with dielectric component. Minor aircraft modifications, such as winglets, will also be considered to provide a site to locate conformal antenna and can improve aerodynamic performance as well. Emphasis should be placed on concepts that will be inherently low cost to retrofit on the AC/MC-130Js. While not part of this development, the antenna array will require the associated backend including: receiver, processor, algorithms, cabling, and miscellaneous equipment to complete the sensor system.

PHASE I: Develop a conformal antenna concept and identify installation locations on the AC/MC-130Js. Define a notional antenna backend. Predict antenna performance as installed on the AC/MC-130Js. Conduct breadboard testing of the antenna concept and demonstrate feasibility through both testing and analytical tools.

PHASE II: Fabricate a scale model of the C-130 and Phase I antenna concept. Conduct performance measurements on model antenna and provide cost estimates for potential retrofits. A final presentation/demonstration will be held at the conclusion of Phase II at Wright-Patterson AFB.

PHASE III: The conformal antenna technology will have many applications for SIGINT capability on existing military/commercial aircraft.

REFERENCES:
1. Callus, P., "Conformal Load-Bearing Antenna Structure for Australian Defence Force Aircraft," 2007.

2. Callus, P., "Novel Concepts for Conformal Load-bearing Antenna Structure," 2008.

3. You, C., Tentzeris, M., Hwang, W., "Multilayer Effects on Microstrip Antennas for their Integration With Mechanical Structures," 2007.

KEYWORDS: CLAS, antennas, conformal, low-profile, load-bearing

AF131-002 TITLE: Aerospace Systems Efficiency Improvements for Legacy Aircraft

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop efficient analysis framework for airframe drag reduction and aeropropulsive efficiency improvement, and use this framework to demonstrate technologies' ability to reduce fuel consumption of Air Force legacy transport/tanker aircraft.

DESCRIPTION: One critical aircraft efficiency enhancement is the reduction of the total fleet fuel burn, and one major avenue is improvement of airframe aerodynamics through minor alternations or retrofit, with minimal or zero adverse impact to mission readiness, maintainability, or other practical considerations. New ideas for drag reduction on near-term and legacy aircraft abound, as the field is old and concepts are easy to advocate. Examples include increase of laminar flow through passive or active means, more clever airframe-propulsion integration, deformable/deployable stall-control and high-lift devices, methods for gust load alleviation, and various flow-control devices. Considerable drag-reduction potential may be found through outer mold-line cleanup by removal of vortex generators and other protuberances that were affixed on legacy aircraft to address problems discovered in flight testing, or which were part of the original design intent. This solicitation aims at novel ways of applying existing concepts, or unique devices or material systems which enable improved aero performance. The intention is retrofit on existing aircraft, and specifically not the complete re-design of the aircraft itself.

Accurate and fast simulation of aerodynamic drag and overall aircraft performance at the conceptual and preliminary design stages is essential for quantifying the effects of small design changes at the system level. The desired method is more advanced and more robust than statistical fits or generalization of classical textbook calculations automated in graphical user interface, and must be computationally more efficient than Navier-Stokes solvers. One possibility is modernization of classic panel methods, to include nonlinear panels, tolerance of non-watertight geometries, parametric geometry definition for rapid analysis of alternatives, and lumped-parameter models of flow control devices. The latter might include flow-through panels to simulate fluidic flow control, or time-dependent body forces to simulate plasma flow control. The method should obviate the need for defining the wake and should take advantage of modern three-dimensional geometry environments. While the focus is on analysis of technologies to improve energy efficiency of legacy configurations, the analysis method should be applicable to modern and future aeroconfiguration concepts, such as distributed propulsion. and modeling of high-lift systems.

In summary, this solicitation is concerned with 1) aircraft drag reduction technologies, 2) quantification of how these technologies impact airplane performance/efficiency and overall fleet efficiency, and 3) an integrated tool set for assessing said quantification in a systematic way suitable for conceptual and preliminary design.

PHASE I: Demonstrate the feasibility of the proposed analysis tool to easily and quickly evaluate drag reduction technologies and their impact on fleet system fuel costs. Initial system architecture and proposed interfaces will be defined. Define new drag reduction schemes and lumped-parameter models and provide the layout and software design of new prediction tools.

PHASE II: Apply analytical framework to assess efficacy of proposed technology for drag reduction and aeropropulsive efficiency enhancement to 1) the entire aircraft and 2) fleet-wide assessment of aircraft. Perform detailed computational analysis of installed devices, validated with relevant wind tunnel data and/or higher-fidelity computations. Demonstrate analytical tool's robustness and accuracy across the performance envelope.

PHASE III: Applications include other DoD aircraft including Foreign Fleets using US equipments. NASA, or private companies, could consider commercial airliners or general aviation aircraft.

REFERENCES:
1. NATO Science & Technology Organization Scientific Publications. A comparison of panel methods for subsonic flow computation, AGARD-AG-241, Jan 1979, AGARD. This report is available to all customers. AGARD flight test www.cso.nato.int, www.cso.nato.int/abstracts.aspx?pg=61&RestrictPanel.

2. NATO Science & Technology Organization Scientific Publications Special Course on Engineering Methods in Aerodynamic Analysis and Design of Aircraft, AGARD-R-783, Jan 1992, AGARD . This report is available to all www.cso.nato.int, www.cso.nato.int/abstracts.aspx?pg=9&RestrictPanel=9.

3. Joseph Katz and Allen Plotkin, Low Speed Aerodynamics (2nd Edition), Cambridge University Press, Cambridge, United Kingdom, 2010.

KEYWORDS: drag reduction modification, excrescence drag reduction, fuel burn reduction, hydrocarbon fuel reduction

AF131-003 TITLE: Evaluation of Unsteady Loading on Store Trajectories

TECHNOLOGY AREAS: Air Platform, Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop and demonstrate an accurate analysis tool for determining aircraft/store combinations of high risk for store trajectory deviations.

DESCRIPTION: The goal of this effort is to provide a quick method (duration of weeks not months) of determining aircraft/weapons store combinations at high risk for this unsteady influence. The ability to identify the portion of the flight envelope which is likely to produce trajectory variations is critical to developing the store certification plan. The ideal tool would be able to identify a flight envelope with areas of potential difficulty flagged for further analysis. This capability is sought for any future aircraft bay environment/store combination.

Development of an analysis tool that can quantify the frequency and magnitude of the aircraft bay aerodynamics coupled with the store stability/flight characteristics to allow rapid model assessment is desired. Identification of the appropriate aircraft flow parameters and the store stability parameters to consider for the model is left to the proposer. The tool will determine configurations that need to be further modeled using computation fluid dynamics (CFD), wind tunnel testing, and/or flight testing. It is desired that the model and supporting documentation be delivered at the end of Phase II effort for further evaluation and testing by U.S. Government personnel. A system demonstration will be conducted at Wright-Patterson AFB at the completion of the Phase II effort.

PHASE I: Develop analysis tool concept and demonstrate proof-of-concept. The tool should characterize both bay unsteadiness and store susceptibility to it. Demonstrate prototype software and begin to populate with data. Formulate Phase II software development plan including verification and validation activities.

PHASE II: Fully develop the modeling tool and produce a database to support selected U.S. Air Force aircraft and stores. Conduct verification and validation strategies developed in Phase I. Identify how aerodynamic parameters will be produced (CFD analysis, wind tunnel testing, etc.) and conduct end of contract demonstration.

PHASE II: Military application includes fighter/attack, bomber, and unmanned aircraft that carry weapons/fuel tanks. Unsteady flow modeling and surface loads tool analysis would be applicable to unsteady flow in automotive, aerospace, or HVAC applications as well as for weather sensor deployment, humanitarian air drops, and search & rescue system deployment where accurate trajectories are important.

REFERENCES:
1. Johnson, R., Stanek, M. and Grove , J. “Store Separation Trajectory Deviations due to Unsteady Weapons Bay Aerodynamics,” AIAA-2008-188, 46th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, Jan. 7-10, 2008.

2. Roughen, K., Wang, X., Bendiksen, O., and Baker, M. "A System for Simulation of Store Separation Including Unsteady Effects," AIAA-2009-549, 47th AIAA Aerospace Sciences Meeting, Orlando, Florida, Jan. 5-8, 2009.

3. Westmoreland, S., “Trajectory Variation Due to an Unsteady Flow-Field,” AIAA 2009-550, 47th AIAA Aerospace Sciences Meeting, Orlando, Florida, Jan. 5-8, 2009.

4. Roughen, K., Gariffo, J., Hammerand, D., and Roberts, R. “Estimation of Unsteady Loading for Sting Mounted Wind Tunnel Models,” AIAA 2011-1941,52nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 19th AIAA/ASME/AHS Adaptive Structures Conference, Denver, Colorado, April 4 – 7, 2011.

5. Neal Kraft, N. “Non-Repeatability of Store Separation Trajectories from Internal Weapon Bays Due to Unsteady Cavity Flow Effects - Lessons Learned from a 2D Investigation,” AIAA-2011-1238, 49th AIAA Aerospace Sciences Meeting and Aerospace Exposition, Orlando, Florida, Jan. 4-7, 2011.

KEYWORDS: aeroacoustics, store separation, unsteady store loads, weapons bay, store trajectory prediction, drop test, store certification

AF131-004 TITLE: Aerodynamic Analysis of Deployed Bay Doors on Modern High-Speed Aircraft

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a cost effective way (process or tool) to evaluate unsteady aero loading on deployed aircraft bay doors, to allow designers to evaluate early in design process.

DESCRIPTION: The U.S. Air Force is required to open doors on many of its aircraft during flight. This ranges from an aircraft's low-speed opening of landing gear doors and speed brakes to opening weapons bay doors in supersonic flight. This sets up a situation for unsteady aerodynamic loading of these surfaces due to their motion into the flow path as well as the potential for unsteady flow oscillations in and around the exposed opening in the aircraft. Deploying weapons bay doors is particularly complex in that the separated flow from the doors themselves interacts with the highly unsteady weapons bay flow which is known to exhibit strong tonal content under many of the flight conditions at which the U.S. Air Force operates its aircraft. These weapons bay tones and the oscillatory nature of the separated flow on the doors have the potential to excite structural modes of the doors, aircraft surfaces, or externally carried munitions and fuel tanks and can lead to buffet, flutter, or fatigue induced failures.

Currently, significant effort is taken to substantiate structural loads design analysis and to demonstrate structural integrity for critical loadings of all aircraft components. This can involve a multitude of testing from finite element modeling to wind tunnel testing of dynamically scaled doors to actual flight testing. The focus here is the generation of the aerodynamic loading on the weapons bay doors and the surrounding aircraft surfaces. Typically steady door loads are collected during sub-scale wind tunnel testing. When model scale permits static pressure mapping and, on rare occasion, dynamic pressure transducers are applied to weapons bay doors to collect mean and fluctuating pressures on rigid doors for detailed analysis. The coupling of the unsteady weapons bay flowfield with the highly complicated three-dimensional (3-D) aircraft surfaces (reference 4) drive the need to accurately model this highly unsteady aerodynamic phenomenon.

To improve the analysis of deploying aircraft surfaces, with specific focus on weapons bay doors, both computational modeling and wind tunnel testing to establish steady and unsteady surface loadings are needed. It is critical that this modeling of a rigid model capture the unsteady character of the fluid dynamics prior to considering deploying doors, transient loading due to store separation, and eventually fully coupled aero-structural modeling during a store separation event. The key aspect of this effort is to accurately capture the magnitude and frequency content of the unsteady surface pressures due to the weapons bay, transient surface motions, and eventually the fluid structure interaction. A geometric build-up approach is recommended in order to isolate the incremental contributions. It is desired that the software and supporting documentation be delivered at the completion of the Phase II effort for additional evaluation by U.S. Government personnel.

PHASE I: Devise a plan to develop a process/tool to obtain unsteady aerodynamic surface loads in and around open aircraft weapons bays. Demonstrate feasibility of these techniques to address flight conditions Mach 0.6 to 5.0 at altitude and experimentally validate to the extent possible during Phase I.

PHASE II: Unsteady aerodynamic surface loads due to weapons bay doors cycling and store separation will be incorporated into the tool. Demonstrate in the transonic and supersonic (Mach 2+) flow regime. Planning will include provisions for coupling of the unsteady analysis tool with structural modeling to provide a unified capability to analyze a fully flexible dynamic store separation with door cycling, leading to a tool to address sonic fatigue, buffet, limit cycle oscillation, and flutter.

PHASE III: Military Application: landing gear aerodynamics, air brake, weapons configuration, and aircraft modifications for sensors, antennas etc. Commercial Application: landing gear aerodynamics, automobile design opening/closing of windows/sunroofs and auto racing movable aerodynamic surfaces.

REFERENCES:
1. R.E. Little, "Aerodynamic Characteristics of Open Weapon Bays on The B-1," Aircraft/Stores Compatibility Symposium Proceedings, Vol. 2, September 2-4 1975, ADA084870 available in DTIC, pp. 791-836.

2. S.J. Lawson, G.N. Barakos, "Review of Numerical Simulations for High-Speed, Turbulent Cavity Flows," Progress in Aerospace Sciences 47 (2011), Elsevier, Ltd., pp. 186-216.

3. Kannepalli, C., Chartrand, C., Birkbeck, R., Sinha, N., and Murray, N., “Computational Modeling of Geometrically Complex Weapons Bays,” AIAA 2011-2774 ,17th AIAA/CEAS Aeroacoustics Conference, 32nd AIAA Aeroacoustics Conference, Portland, Oregon, June 5-8 2011.

4. Flight test photos of a modern fighter aircraft weapons bay http://www.jsf.mil/images/gallery/sdd/f35_test/a/sdd_f35testa_068.jpg.

5. Murray, N., Jansen, B., and Rich, D., “Effect of Door Configuration on Cavity Flow Modulation Process,” AIAA-2011-2773, 17th AIAA/CEAS Aeroacoustics Conference, 32nd AIAA Aeroacoustics Conference, Portland, Oregon, June 5-8 2011.

KEYWORDS: aeroacoustics, weapons bay acoustics, unsteady fluid dynamic loads, weapons bay loads, weapon bay door loads, acoustic fatigue, weapons bay doors, dynamic loads

AF131-005 TITLE: <u>Innovative Propeller Multi-Point Multi-Disciplinary Optimization</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a process for multi-point propeller optimization for a range of vehicles, particularly mobility transports. Include method for analyzing propulsion system, airframe/propulsion integration, acoustics, cruise and takeoff performance.

DESCRIPTION: For subsonic aircraft, increasing turbine bypass ratio is conducive to lower thrust-specific fuel consumption. Studies have shown that an increase in turbine bypass ratios is a primary driving factor in achieving overall efficiency improvement for subsonic transport aircraft. The limiting case for high-bypass ratio is a turboprop, then for higher performance applications, the open-rotor propulsion system. The latter is the higher-speed and higher-solidity analogue of the former, and its application is for larger, higher speed subsonic transports. But with large increases in turbine power comes more complicated open-rotor staging, blade operation, and gearing integration. This and its airframe integration may negate the benefits to overall system efficiency. Modern designs of open-rotors suggest capacity for high subsonic cruise together with good takeoff/landing performance, but modern open-rotor designs are subject to ambitious air-transportation noise constraints. Methods of propeller or open-rotor analysis tend to either be very low-order, or proprietary. Research engineers cannot render rational systems decisions without access to accurate flexible design methods. Such methods must be multi-disciplinary if they are to be useful in conceptual design of complex and innovative aircraft, with subject-disciplines including aerodynamics, fuel burn rate, weights, acoustics, structural dynamics, and gear coupling between the propellers, gear chain and turbine engine. The relatively efficient fixed propeller designs tend to be single-point performance, at least at the level of conceptual design. Thus, there is a need to develop the design framework for multi-point optimization of efficient propellers – for example, for cruise, climb and loiter, takeoff and landing. Propeller aerodynamics and orientation flexibility therefore need development in two senses: first, to improve efficiency per se; and second, to raise efficiency across the expected operating envelope. Also, in a propeller-driven or open-rotor-driven aircraft, an important practical performance consideration is vehicle acoustic footprint, which depends for example on blade tip Mach number, blade airfoil design, and placement of the propeller disk relative to the aircraft fuselage and other components. As with propeller selection itself, many of these considerations have been approached empirically. The lack of unified engineering understanding has led to suboptimal designs. A comprehensive, non-proprietary tool is necessary for propeller and open-rotor designs at the conceptual level, relevant to future advanced subsonic aircraft needs.

PHASE I: Develop the feasibility of a multi-point design optimization tool. Develop the preliminary architecture for a computational/analytical propeller and open-rotor design tool, to include blade sizing, design and orientation flexibility; hence, first-order aerodynamic propulsive performance prediction. Assess opportunity for multi-point blade efficiency improvement with suitable shaping.

PHASE II: Fully develop and demonstrate the design system tool to include 1) acoustic signature for the propeller in isolation, and 2) propellers installed in pusher and tractor configurations. Using simulated flight test, wind tunnel test and/or numerical assessment, demonstrate improvements in takeoff and landing, cruise, loiter and dash efficiency, and show robustness of efficiency improvements across a range of scales and applications.

PHASE III: Applications include USAF legacy aircraft and commercial airliners currently using turbofans, which conceivably could be replaced with open-rotors.

REFERENCES:
1. Gur, O., and Rosen, A., "Optimization of Propeller Based Propulsion System," J. Aircraft, Vol. 46, No. 1, January-February 2009.

2. Hill, P., and Peterson, C., "Mechanics and Thermodynamics of Propulsion," Addison-Wesley Publishing Company, November 1970.

KEYWORDS: propeller, optimization, blades, aerodynamics, open rotor, acoustics, fuel burn

AF131-006 TITLE: System of Systems (SoS) Certification Techniques

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To develop analysis techniques for the safety verification and validation of complex, autonomous system of systems (SoS) in order to prevent unintended interactions by addressing SoS challenges: interoperability, emergence, evolution, and non-determinism.

DESCRIPTION: Safety-critical software being developed for collaborative autonomous aerospace systems is rapidly growing in size and complexity. Current methods of verification and validation (V&V) of this type of software lead to increased development costs, are time-prohibitive in testing, and create significant impacts to warfighter deployment and sustainment. This need is highlighted in the Air Force's 2010 Technology Horizons, "It is possible to develop systems having high levels of autonomy, but it is the lack of V&V methods that prevents all but relatively low levels of autonomy from being certified for use." As today's systems become more complex, there is a growing issue of unintended interactions within a single system and on a macro-level within a SoS. As systems are composed into a larger system, behaviors begin to emerge that did not exist at the individual or loosely coupled level. Therefore, one can easily see how the whole SoS architecture is greater than the sum of the parts. As the complexity of these more advanced systems increases, their non-linearity and non-deterministic qualities increase as well. This increased complexity can lead to instances of unintended interactions which may violate the safety and certification constraints of the system being developed. As systems become more tightly coupled, unintended interactions become more pronounced. An easy-to-understand example of this is the national highway system. Under light traffic, minor braking and acceleration among the various vehicles go largely unnoticed. As traffic increases, this braking and acceleration has a traffic wave effect through the entire system. This emergent behavior can be seen throughout most other SoS, such as air traffic control, internet traffic, aircraft development, operation of remotely piloted autonomous aircraft (RPA), automotive system development, and data-centric systems. A parallel example to the national highway system mentioned above is that of autonomous systems operating in the terminal area of an airport. As the dynamic, integrated, and rapidly changing environment of terminal area traffic fluctuates, the SoS interactions can lead to unpredictable results from autonomous systems. This lack of predictability (and non-determinism) causes a lack of trust and difficulty in certifying these systems.

The overall vision for this research area is to reduce reliance on testing and enable SoS certification through trusted, formalized, and safe interactions of certified systems with focus both on single systems and within a SoS. As a step toward that goal, this SBIR topic looks to develop analysis and modeling techniques that focus on analysis of SoS versus exhaustive tests through technologies such as formal specification, boundary certificates, and predictions of system interactions. Through the use of the modeling tools and analysis techniques developed under this SBIR, it is suggested that more stable and easily scalable systems can be developed. The goal of this SBIR is not to develop a better low-level interface control document (ICD) management system, but rather focus on improved, system engineering modeling tools and analysis techniques that lead to formally provable and guaranteed safe interactions. Through the elimination of unintended interactions, especially during the evolutionary stage of a SoS life cycle, more trusted and autonomous systems will become a reality.

PHASE I: Demonstrate the feasibility of a methodology and associated tools to enable SoS interaction analysis and future certification methods for autonomous systems. A description of the proposed system and associated methodology is required. Modeling and simulation may be needed to fully demonstrate system feasibility and operation.

PHASE II: Continue to develop the tools and methodology proposed during the Phase I system. A challenge problem will be determined in the area of autonomous systems and a final Phase II demonstration will be conducted to inform interested personnel of the technology development in the area.

PHASE III: Military Application: This technology has the ability to enable many advanced capabilities for unmanned aerial vehicles (UAVs), such as automated aerial refueling (AAR) and adaptive control, by providing safety guarantees for systems that cannot be exhaustively tested.

REFERENCES:
1. Selberg, S., and Austin, M.A., "Toward An Evolutionary System Of Systems Architecture," Institute for Systems Research, University of Maryland. The International Council on Systems Engineering (INCOSE), 2008. Web. May 9, 2012. <http://ajcisr.eng.umd.edu/~austin/reports.d/INCOSE2008-Paper378.pdf>.

2. Technology Horizons - A Vision for Air Force Science & Technology During 2010-2030 http://www.af.mil/information/technologyhorizons.asp.

KEYWORDS: system of systems, SoS, certification, safety critical, adaptive control, verification, validation, V&V, complex systems, architectures, emergent behavior, interoperability, evolution, non-determinism, interface, ICD, RPA, Autonomous, UAV, remote piloted vehicle

AF131-007 TITLE: Strain Measurement System for Operation in Extreme Environments

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop robust deployable strain gage system to interrogate strain in extreme thermal (minimum 1600° F), acoustic (~165 dB) and dynamic frequency loading conditions.

DESCRIPTION: The U.S. Air Force has a critical need for robust sensor technologies applicable to structural response strain measurements in extreme and harsh environments. This sensor technology is vital for the verification of new analytical methods and the validation of advanced structural concepts and technologies with relevance to the Air Force's Prompt Global Strike and Response Space Access initiatives. Air Force Research Laboratory (AFRL) testing has shown traditional resistive strain gages fail due to the extreme test conditions and at best yield erroneous data due to disproportionately large thermal response and instability of the gage material. In addition, resistive gages have poor repeatability and hysteresis due to thermal aging. Several sensor technologies that have shown promise for accuracy and survivability in the extreme temperature conditions of hypersonic flight are the Extrinsic Fabry-Perot Interferometer (EFPI) optical sensor, the Fiber-Bragg Grating (FBG) optical sensor and the optical backscatter reflectometer (OBR) sensor. The goal of this effort would be to develop a hardened gage, appropriate sensor to signal conditioning interconnects and necessary signal conditioning that can evaluate both static and dynamic strains in a high-temperature environment under static and dynamic loads. It is important to note that there are several commercial strain sensing technologies available, capable of dynamic strain measurement within such an environment. However, no measurement technology is available to accurately interrogate static strain within such an extreme environment. The final result of the effort would produce a system that 1) can provide accurate static strain measurements up to 20,000 µm/m from combined thermal and static load at temperatures of 1600 °F or greater, 2) can provide accurate strain measurement data while subjected to high acoustic loading (165 dB overall sound pressure level), 3) can provide accurate dynamic strain measurement under dynamic loading (0 to 1 KHz) equivalent to +/- 250 µm/m, 4) can provide accurate strain measurement data in any combination of the aforementioned loading within 10-percent error, and 5) can provide 0 to 10 volts direct current (VDC) data acquisition (DAQ) analog output signal, proportional to strain measurement.

PHASE I: 1) Demonstrate and document the aforementioned strain system for application in extreme environments, 2) develop a sound technical approach to overcome the shortfalls of the system or propose an alternative technology that meets the performance criteria, and 3) perform experiments to independently validate at minimum thermal and if possible acoustic, and dynamic solutions.

PHASE II: Develop prototype strain system that can operate within the combined thermal static/dynamic loading conditions experienced in a hypersonic flight environment. Show statistical data supporting the durability and accuracy of developed system, appropriate for a TRL 4 designation. The prototype must be suitable (small package, non-invasive) for installation on high-temperature metallics and non-metallic composite aerospace structures.

PHASE III: MILITARY APPLICATION: This technology would be used in the structures testing of current and future U.S. Air Force hypersonic aerospace vehicles. COMMERCIAL APPLICATION: This technology is applicable to the validation of commercial space vehicles, manned and unmanned, and advanced engine materials.

REFERENCES:

1. Anthony Piazza, "High-Temperature Sensor Applications for Ground-Testing Of C-17 Engine," NASA Dryden Research Facility.

2. Characterization of a FBG strain gage array embedded in composite structure, Yu Fan, Mojtaba Kahrizi, Electrical and Computer Engineering, Concordia University, Montreal, Que., Canada.

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KEYWORDS: high-temperature strain measurement, apparent strain, high-temperature strain sensor, extreme environment, strain measurement

AF131-008 TITLE: Remotely Piloted Aircraft (RPA) Postern Sense and Avoid (SAA)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Identify approaches to achieving postern (rear-looking) sense and avoid (SAA) for remotely piloted aircraft (RPA). Develop the most promising and commercially viable candidate. Demonstrate performance and capability in a relevant environment.

DESCRIPTION: Usually when people think of mid-air collisions (MAC), they envision encounters involving two aircraft approaching with head-on or converging trajectories, each aircraft in the other's field of view (FOV). In such encounters the pilot of each vehicle can conceivably see the other aircraft in time to react and avoid disaster. However, Federal Aviation Administration (FAA) statistics indicate that 80 percent of MACs result from one aircraft overtaking another from behind. Of these, 30 percent of the faster moving aircraft approached between 0 to10 degrees of the slower aircraft's tail — nearly directly behind. These statistics were compiled on piloted aircraft. Because many RPA fly slower than piloted aircraft the incidence of overtakes is expected to rise as RPA airspace integration increases.

Pilots are already concerned about overtaking and colliding with RPAs. RPAs fly slower are less maneuverable, have lower climb rate capability, are smaller on average than other traffic (e.g., RQ-7 Shadow), and sometimes are camouflaged to be hard to detect visually. RPAs create additional challenges to pilot SAA because RPA missions can involve hovering (e.g., M/RQ-8 Fire Scout) or circling in one location. However, some RPA are comparable in size and cruise airspeed to general aviation aircraft (e.g., MQ-9 Reaper) and able to climb to mid-level altitudes and higher. But these mid-to high-level altitudes are historically populated by much larger commercial airliners and military traffic flying at much higher speeds. During overtakes this size difference and high closure rate make it difficult to detect an RPA until it is too late to avoid a MAC. While the Traffic Alert and Collision Avoidance System (TCAS) and the Automatic Dependent Surveillance Broadcast (ADS-B) system mitigate the response time problem, not all aircraft are so equipped. Added to this risk is the tension created by current FAA rules-14CFR, Part 191, Section 91.113-which place the SAA burden on the overtaking pilot(s). From a pilot's standpoint, RPA presence causes an elevated risk of an overtaking MAC.

Current RPA SAA development efforts address forward-looking field of regard (FOR) requirements using multiple sensors. The purpose of the research proposed here is to explore methods/techniques to alleviate the overtaking MAC hazard described above for Group 2 through 4 RPA. To benefit both piloted aircraft and RPA, this system should not be dependent on the existence of an onboard forward SAA system.

The objective is to explore the unique aspects of postern SAA, develop the most technologically promising and commercially viable candidate, and demonstrate the capability to be safe and effective. Known challenges include 1) airframe vibration and engine exhaust hindering valid detection and accurate position estimates (the goal is detect postern collision hazards not less than +/- 25 degrees in azimuth and elevation during day and night), 2) timely detection and tracking to provide not less than 30 seconds prior warning of aircraft with up to 120 knots overtake speed (the warning notification should contain as much information about the overtaking aircraft as possible (e.g., altitude, heading, airspeed), but relative azimuth and elevation as a minimum), and 3) sensor(s) selection to minimize size, weight, and power, and leverage forward-looking SAA sensor information (e.g., those which are omnidirectional) as appropriate.

PHASE I: Identify approaches to attain postern SAA. Determine requirements and desired performance. Propose a candidate architecture. Identify equipment, hardware, and components as applicable. Begin algorithm development. Establish feasibility through modeling and simulation or other demonstration.

PHASE II: Finalize the architecture, validate model, and mature algorithms/software. Apply design to fabricate a prototype. Demonstrate postern SAA through modeling and simulation or other demonstration.

PHASE III: Goal is transition to operational use. Capability will be further matured to support/augment military SAA systems fielded or in development by producing a system of sensor(s)/algorithm(s)/hardware for a TBD platform. Application as a stand-alone system for piloted aircraft will also be considered.

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KEYWORDS: collision, RPA, overtake, see and avoid, sense and avoid, mid-air collision, MAC, field of regard, postern

AF131-009 TITLE: Low-Observable Heat Rejection from Aircraft

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Future aircraft-based high energy lasers will produce hundreds of kilowatts of low-quality waste heat. Novel approaches are sought to remove waste heat under these conditions without significant impact on aircraft signature/aerodynamic performance.

DESCRIPTION: The large quantities of low-quality (<40C) waste heat generated by directed energy and other electrically based technologies need to be removed from air platforms in a manner that will allow the system to meet size, weight and power constraints and not interfere with aircraft operation. Heat from directed energy systems is often generated in laser diodes with junction temperatures from 20C-30C as required for the desired pump laser wavelength. Most laser diode packages require non-electrically conductive working fluid with the current state of the art being de-ionized water which is undesirable for airborne logistics reasons. Due to the high peak heat flux of laser systems (~1MW), thermal storage is often used during system firing and a smaller, steady heat sink will recharge the thermal storage. The heat removal capacity of fuel as working fluid is at or near its capacity in future and current air platforms. Heat sinks are being sought that do not involve transferring heat to the fuel. Non-fuel heat sinks have the potential to add to the aircraft thermal signature, radar cross section or adversely impact the aerodynamic performance of the platform. The successful proposal will investigate heat sinks which do not significantly impact the thermal signature, radar cross section or the aerodynamic performance of sub and transonic aircraft and which have the capacity to continuously remove up to 100kW of heat at less than <40C at altitudes from 10kft to 40kft.

PHASE I: Phase I will conduct a study examining heat sinks involving a variety of technologies, evaluating them for aircraft impact, heat removal potential, SWaP and potential for flight worthiness. At a minimum, the following should be considered: retractable fins, louvered scoops, third stream engine air, convection from aircraft skin and blow-down of engine and exhaust compatible substances.

PHASE II: Phase II will build a subscale prototype system capable of being tested on surrogate heat sources in an appropriate vibration or wind tunnel facility. The Air Force Research Laboratory, Directed Energy Directorate, is able to provide testing facilities.

PHASE III: Phase III will demonstrate the prototype system on a compatible aircraft with a suitable directed energy system or surrogate heat source.

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KEYWORDS: Thermal management, directed energy, aircraft heat sinks, low-observable

AF131-010 TITLE: Transient Electromagnetic Simulator for EMP Survivability Analysis of Packaged Electronic Systems

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Provide transient simulation capabilities of high-power electromagnetic interference for signal/power distribution networks of packaged electronics.

DESCRIPTION: Implementing the computer-aided design (CAD) tools for modeling of high-power electromagnetic interference (HPEMI) effects, caused by electromagnetic pulses/high-altitude electromagnetic pulses (EMPs/HEMPs), at the platform (airplane) level is hindered by both the complexity of modeling the electromagnetic coupling paths through a physical structure of the platform and the complexity of integrated circuit (IC) chipsets that house the packaged electronic blocks (digital, analog, radio-frequency), whose functionality degrades significantly as a result of HPEMI. While significant progress has been made in modeling the complexity of the electromagnetic coupling path [1-3], very little progress has been made in the development of systematic modeling methodologies that address the complexity of IC chipsets and their connecting traces/cables that house the power distribution network of packaged electronic blocks. Since the power distribution network serves as the primary conduit for HPEMI effects found typically in many printed circuit boards (PCBs), the inclusion of the electromagnetic (EM) modeling that treats the details of the interactions between IC chipsets and connecting traces/cables in the packaged electronic blocks becomes a critical issue in the development of a reliable and accurate HPEMI analysis tool.

Specifically, this project looks for a CAD based tool needed for determination of the geometry-dependent, parasitic impedances, such as per unit length (PUL) inductance matrix L, PUL capacitance matrix C and PUL resistance matrix G, which are essential input parameters used in transient multi-conductor transmission line (MTL) simulators, that reflect on details of the coupling interactions for IC chipsets and connecting traces/cables in packaged electronic blocks in the frequency range that spans from 100 MHz to 10 GHz. It is important that the developed CAD tool is capable of designing and creating the layout of complex IC chipset and connecting trace/cable structures, represented as shielded inhomogeneous dielectric and conductive media, since the layout itself contains the necessary material and cross-section area information that one needs to solve the static 2 D Laplace equation for geometry-dependent, parasitic impedances. The static 2 D Laplace equation needs to be solved, as part of the CAD based tool, for electric field potentials using either the finite difference or finite element technique in order to handle any shaped geometries of connecting traces/cables. The calculated potentials are, in turn, used to solve for per unit length (PUL) inductance matrix L, PUL capacitance matrix C and PUL resistance matrix G using the generalized MTL inductance matrix formulation, the generalized MTL capacitance matrix formulation and the generalized MTL resistance matrix formulation, respectively.

In addition, the developed CAD based tool needs to be incorporated within a transient MTL simulator as part of the overall CAD based simulation tool to provide seamless interfaces with traditional circuit analysis simulators, such as Simulation Program with Integrated Circuit Emphasis (SPICE) [4], and transient EM field simulators, for carrying out the HPEMI effects analysis on packaged electronic blocks, such as PCBs, as a result of the E1 (early-time) component of the HEMP waveform that lasts about 100 nanoseconds in duration at peak electric field levels of about 50 kilovolts/meter.

PHASE I:  Develop a methodology for a transient MTL simulator that can handle the complexity of the power distribution network in packaged, integrated circuit chipsets with the requirement that the transient MTL simulator has seamless interfaces with industry standard SPICE circuit analysis simulators and transient electromagnetic field simulators.

PHASE II:  Based on the methodology developed in Phase I, develop and demonstrate a CAD based tool for the calculation of parasitic impedances, used as inputs to a transient MTL simulator, that are applicable for HPEMI effects analysis of packaged electronic blocks in the HEMP environment. Also, develop and demonstrate a CAD based transient MTL simulator to interface seamlessly with industry standard SPICE circuit analysis simulators and transient EM field simulators.

PHASE III:  Combine the transient EM simulator with the system-level, HPEM effects codes, such as JREM [5], to perform comprehensive system-level analysis of HPEMI for supporting the overall system designs of noise-immune, packaged electronics for military and industrial communication applications.

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Transient simulation, electromagnetic modeling, electromagnetic interference, electromagnetic pulse, EMP, HEMP, electronic package simulation

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KEYWORDS: Transient simulation, electromagnetic modeling, electromagnetic interference, electromagnetic pulse, EMP, HEMP, electronic package simulation

AF131-011 TITLE: <u>Fiber Optic Amplifier Pump Combiners with Signal Feed Throughput</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop efficient high-power fiber-optic pump combiners to inject multimode laser pump power into large mode area fibers for kW all fiber amplifier architectures.

DESCRIPTION: High power fiber master oscillator power amplifiers (MOPA) enable the development of Air Force Research Laboratory (AFRL) directed energy systems. The AFRL long term goal is to promote the readiness level of this technology so that powerful, lightweight and reliable amplifier units can be mounted onboard next generation aircraft. Reliable high power fiber lasers/amplifiers also spur commercial opportunities in laser well boring, hole punching, cutting, and welding other material processing amplification. The desired characteristics of a MOPA include monolithic construction; i.e., no free space optical components, an output power exceeding state-of-the-art at 1064nm, polarized emission, and fundamental transverse mode operation. This is typically implemented using several stages of optical amplification in Ytterbuim (Yb) doped double clad gain fiber. Clearly the final amplifier stage is the most critical since every component is subject to extremely high power levels. This topic focuses on one of these critical components, the all-fiber pump + signal combiner.

The pump + signal combiner serves to inject multi-transverse mode pump light (976nm for Yb-doped fiber amplifiers) from multiple fiber-coupled diode laser banks into a single double clad and large-mode area fiber. The output is spliced to an ensuing gain fiber or the gain fiber can be directly integrated into the combiner. The injected pump light is subsequently absorbed by the Ytterbium ions embedded in the fiber core so as to amplify the seed signal. The typical combiner launches the pump light so that it propagates in the same direction as the 1064nm signal, co-pumping. However, for narrow spectral linewidth operation it is preferable to launch the pump light opposite to the signal. Counter-pumping may provide some mitigation to the onset of Stimulated Brillouin Scattering thus improving the power range of the amplifier. The ideal pump combiner minimizes the coupling losses between the pump diodes and the gain fiber. It also has minimal loss for the signal, and it preserves the polarization state of the throughput signal being amplified.

Combiners are needed that are compatible with commercially available polarization-maintaining (PM) large mode area (LMA) fibers. Combiners for photonic crystal fibers (PCF) are needed for innovative concepts. In both cases, demonstration of a counter-pumped configuration is desirable. Each input fiber of the pump combiner must be able to handle greater than 300W with a 200µm fiber within a numerical aperture of less than 0.22. The combiner must prove reliable and robust. It must be system integration ready into robust fiber amplifier architectures. Pump insertion loss (a goal of <0.25 dB), signal insertion loss (a goal of <0.4dB), and mode preservation should be addressed.

PHASE I: Design and model concepts of high-power fiber laser pump combiners to establish fabrication and performance feasibility. Fabricate kilowatt capable power combiner prototypes for pump coupling to dual-clad Yb-doped large mode area fibers is required. Criteria for the design include brightness preservation, power handling capability, polarization preservation and robust packaging.

PHASE II: Based on Phase I designs, models and prototype demonstrations, conduct in-depth characterization of hardware to prove maturity of technology toward potential military and commercial applications. The components and characterization data will be delivered to AFRL for insertion into a kilowatt-class fiber amplifier.

PHASE III: In Phase III the kilowatt combiner will be built and reliability tested for military significant environments and packaged for system insertion and commercialization. A multi-kilowatt (>2kW) counter-pumped combiner utilizing advanced photonic-crystal signal fibers must be demonstrated and delivered.

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KEYWORDS: fibers, components, lasers

AF131-012 TITLE: Novel Phased Array Beam Director Development

TECHNOLOGY AREAS: Sensors, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a novel, fully functional high energy laser phased array beam director architecture with supporting analysis to quantify size, weight, power, thermal and mechanical responses to include global and sub-aperture jitter components.

DESCRIPTION: The US Air Force is seeking to place a low size, weight and power (SWaP) phased array laser weapon on an air platform. Additionally, a fuselage conformal system is desired in order to eliminate the aero-dynamic drag generated by a conventional turret and dramatically reduce the severity of the aero-optics distortion. This development focuses on a novel fuselage conformal beam director for such a phased array laser system.

The designed director will accommodate all acquisition, pointing, and tracking (APT) functions currently defined in one or more of the existing phasing algorithms over a wide field-of-regard operating under the conditions set by the expected engagement scenarios provided by the Air Force Research Laboratory in the references. The beam director system must fit into a small enclosed space and will have limited external area for the pupil. Ideally the beam director will be completely conformal to the fuselage and beam steering will be accomplished electronically. The beam director must be able to handle the thermal and optical requirements necessary of a weapons class laser power. Use of beam combination technology is acceptable as is spatially distributing a number of fibers in each sub-aperture. The high energy laser array fill factor must be high. The beam director must be robust under a variety of mechanically and thermally stressing conditions endemic to the airborne environment, while also maintaining a low SWaP footprint.

While several target based phase sensing, synthetic aperture imaging techniques, and local phase stabilization schemes have been developed under previous efforts, none have been implemented. We are seeking innovative engineering and design solutions in order to realize and implement the theoretical research that has been performed. Refinements to these theories for implementation in the beam director are relevant to this effort; however, the development of new phasing and beam control techniques is beyond the scope of this topic.

Important items under consideration in this effort are: nominal responses to mechanical vibrations including jitter, thermal response, optical train packaging and performance, and thermal, mechanical, and optical isolation and control. Nominal vibrational data can be provided upon request for jitter analysis and simulation. Special consideration will be given to new and novel optical techniques to improve performance or reduce the SWaP footprint while maintaining excellent beam and phasing control.

PHASE I: Identify the technology to develop and deliver a fully functional beam director concept that shows traceability to an airborne platform.

PHASE II: Develop, analyze, and deliver a detailed optical/mechanical design where the analysis is focused on the optical, mechanical, and thermal response of the beam director. Develop a laboratory prototype, funding and schedule permitting.

PHASE III: Integration of the beam director into a complete functional laser array system using a high energy laser. Field demonstration of the system. Possible dual use applications in free space laser communication and astronomy.

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KEYWORDS: optical phased array, phased array, beam director, high energy laser, aircraft platforms

AF131-013 TITLE: Fiber Interface Thermal Management

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop an end of fiber holding and cooling system for high power (>1kW) fiber amplifiers.

DESCRIPTION: The demands placed upon the last 10 cm of fiber used in high power Yb:silica fiber amplifiers can be strenuous. First the laser emission is accompanied by large amounts of residual 976nm pump that must be extracted and absorbed. Second the high energy density of the lasing emission can result in severe facet heating and even catastrophic failure. This is due to absorbing contaminants on the facet surface or scratches. And third, they must be accurately held in place for pointing stability. This latter issue is accentuated by temperature fluctuations as the laser is cycled from off to maximum power. And while the first two issues can be easily addressed, it is this pointing stability criterion that adds significant complexity to the problem. Traditional thermal management techniques have not been employed due to the small spatial scales involved.

Novel approaches are being sought to address fiber holding and thermal management in the vicinity of optical fiber facets for amplifiers that develop over 1kW in output emission. The envisioned device is a fiber holding and cooling system on the last few centimeters (up to 10cm) of a large mode area fiber with, and also without, a fused silica end cap attached. The device is to rigidly hold and cool the fiber with minimal effect on the optical characteristics of output radiation due to mechanical or thermal stress. The heat load can be on the order of 100W. The holder cannot significantly alter the wavefront, polarization or mode structure of the optical radiation. The pointing stability should be less than 1 micro-radian and also not be compromised as the amplifier power (i.e. the heat load) is increased. Actuated tilt control of the device should be considered. The impact of jitter due to the cooling system is to be addressed. Future applications (Phase III) may involve close-packed arrays of fibers. Hence it should be easily adapted to a small packing size or multiple fibers.

PHASE I: The successful effort will develop a proof of concept, which includes materials development, and packaging verified by finite element analysis modeling.

PHASE II: A deliverable prototype for a single fiber will be constructed, validated, and delivered to AFRL/RDLA for evaluation. Concepts for holding multiple fiber amplifiers will be presented.

PHASE III: In Phase III, the technology will be completed on a single multi-kW fiber amplifier. A prototype for multiple fibers (5-10) will be built. The technology will be transitioned to government/industry.

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KEYWORDS: fiber, cooling

AF131-014 TITLE: Aimpoint Maintenance of Ground Targets by Airborne Laser Systems

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a robust algorithm for an airborne system that maintains precision pointing of a laser to an arbitrary point on a surface target that is changing pose. Transition algorithm into software with sufficient documentation and testing.

DESCRIPTION: The military and law enforcement, for either suppression or surveillance, continue to have a need for laser systems on airborne platforms for the engagement of targets on the ground or water surface. For the optimal deposition of energy from a laser beam on an uncooperative target, a laser beam control system must accomplish three tasks: (1) precisely track the target (to within micro-radian precision, and accommodate a sample rate of ~4000Hz), (2) offset the laser pointing from the track line-of-sight to the desired aimpoint on the target, and then (3) maintain the laser beam on the desired aimpoint for the duration of the engagement. The term “aimpoint maintenance” refers to the accomplishment of tasks (2) and (3), and assumes that task (1) is already being accomplished by another algorithm. Although aimpoint maintenance is the subject of this SBIR, a single algorithm that accomplishes all three tasks is also welcome.

For the purposes of this SBIR, assume that the target undergoes a relatively large change in aspect with respect to the line-of-sight of the beam control system. In this case, a fixed angular offset from the track algorithm line-of-sight is insufficient to precisely maintain the aimpoint. Also assume that the desired approach for aimpoint maintenance must minimize drift in the designation of the aimpoint during the engagement. Specifically, the desired precision goal, generically, would be to maintain the aimpoint on a target to within a drift that would permit fluence from the beam to accumulate in a very localized arbitrarily chosen spot on the targeted object. The smaller the drift, the better. In addition, assume that the aimpoint may not only be on the surface of the object, but may be within the object. Next, assume that the aimpoint may be on a featureless portion of the target. Last, assume that a model of the target is not available prior to acquisition by the laser system.

The government is seeking SBIR proposals that hold promise for the development of a robust aimpoint maintenance approach that could potentially be implemented in a laser beam control system. The approach for aimpoint maintenance should be achievable in a reasonably practical beam control architecture. Approaches that are not specific to a particular target are preferred, but proposals that are target specific would also be accepted for consideration.

PHASE I: Develop a robust algorithm that maintains the laser aimpoint on a target that is changing pose. The government will provide the required target scenes via a software module, which can be called by either MATLAB or C language, and run by Windows 32 or 64 bit versions. The scenes will include intensity artifacts due to scintillation (as a result of active illumination) and atmospheric turbulence.

PHASE II: Transition the algorithm from Phase I into deliverable hardware with sufficient documentation and testing. To support government evaluation by simulation and field testing, integrate the hardware with a government track processor located at Kirtland Air Force Base, NM. The H/W must communicate with GE Faunc reflective memory PCIE-5565PIORC-101000 and fit into a 4U rack-mount and consume no more than 400W electrical power on average. The government will provide further interface requirements.

PHASE III: Couple the deliverable software/hardware tool from Phase II with a simulation model and a library of synthetic scenes to serve as a training tool by both military and law enforcement operators on aircraft. The object would be to mark or damage vehicles.

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KEYWORDS: laser, weapon, target, aimpoint

AF131-017 TITLE: Color Ultrahigh Definition Microdisplay (CUDM)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Color ultrahigh definition microdisplay with 8 Mpx (3840x2048) image resolution and 12-bit dynamic range (greyscale) running at 72 Hz for application in day/night pilot helmet mounted display (HMD) systems.

DESCRIPTION: Current helmet-mounted display (HMD) systems can NOT provide the threshold visual acuity (e.g. Snellen 20/20) over the threshold (minimum desired) 40x32-deg field-of-view (FOV). The Joint Helmet Mounted Cueing System (JHMCS) uses a micro-cathode ray tube (uCRT) to provide see-through symbology with an image resolution of about SVGA (800x600, or 0.5 Mpx) over a 20-deg. conical field-of-view (FOV), which approaches, but is less than, 20/20 acuity. Unfortunately, state-of-the-art digital flat panel HMD systems now in development provide just SXGA (1.3Mpx) resolution over about a 40-deg. FOV, which means warfighters must come twice as close to targets to see what they would have seen if provided with a 20/20 acuity battlespace visualization system (e.g. 1 km vs. 2 km, or 100 vs. 200 m). And a 40-deg. FOV is NOT large enough (120x80-deg. is desired), but is just the minimum needed to avoid excessive head scanning to maintain situational awareness. A spatial image resolution of about 8 Mpx (3840x2048) is required to provide 20/20 acuity for each 40-deg. conical portion of the FOV, vs. 1.3 Mpx state-of-the-art for several microdisplay technologies, including emissive active matrix organic light emitting diode on silicon substrate (AMOLED), transmissive active matrix liquid crystal display on glass substrate (AMLCD), reflective active matrix liquid crystal display on silicon substrate (LCOS), and reflective and interferometric microelectromechanical systems (MEMS). And for avionics applications helmet integration volume requirements require the display to be in a 12-mm (0.5-in) diagonal form factor, which requires pixels to be reduced in size from 12-um to 4-um, which is now within the fabrication state-of-the-art. Separately, current displays support a dynamic range of just 8-bit (256 grey levels) compared to the perceived real-world 'display' dynamic range of 18-bit, and to new solid-state sensors that are demonstrating dynamic range of over 12-bit. New, ultrahigh definition microdisplays are needed for HMD applications with an octave higher (4X) resolution, or 5 Mpx (threshold) to 8 Mpx (objective) (e.g. formats of 2560x2048 threshold to 3840x2048 objective) and with a dynamic range (grayscale) of at least 12-bit. The frame rates need to be increased from the 30-to-60 Hz in available miniature flat panel displays to 72 Hz (threshold) and 96 Hz (objective) for avionics applications due the motion of pilots through the sky and rapid head movements within the cockpit. Approaches to the imaging device (microdisplay) range from traditional (miniature AMLCD, AMOLED, LCOS, MEMS) to novel (hologram projectors). Approaches to the optics that relay the miniature real image from the microdisplay and magnify it to the large-FOV large-eyebox virtual image perceived by the eye may range from classical (refractive/diffractive) to novel (e.g. waveguide, holographic waveguide). Efforts that can make credible progress towards these threshold and objective goals are sought.

PHASE I: Design color ultrahigh definition microdisplay system with threshold image resolution of 5 Mpx for 40x32-deg FOV. Demonstrate manufacturability of design that leverages commercial product trends in terms of pixel density: 4-um monochrome pixel pitch for manageable avionics 12-mm die image size.

PHASE II: Fabricate color ultrahigh definition demonstration device and perform characterization testing for uniformity, dynamic range, and frame rate. Deliver at least three microdisplay demonstration devices that provide usable imagery for evaluation for HMD application. Develop a roadmap for ultrahigh definition microdisplays with off-ramps for specific products leveraging commercial fabrication facilities.

PHASE III: Military applications include HMD systems for pilots (all aircraft), tankers, and dismounted combatants. Commercial applications include homeland security, police, and entertainment (TV games).

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5. Microdisplays based on eMagin’s active matrix organic light emitting diode (AMOLED) approach with 800x600 11.1-um color triad pixels may indicate fabrication potential enabling potential 2400x1800 4-um green pixels device with an 8x8x6.6 mm viewing area and 19.8x15.2x5.0 mm (0.44-in form factor) mechanical dimension, http://www.emagin.com/products/OLEDMD/OLED_microdisplays.php (accessed 1 March 2009).

KEYWORDS: Microdisplay, HMD, ultrahigh definition, spatial image resolution, dynamic range, field-of-view, angular visual acuity, AMLCD, AMOLED, LCOS, Q-Sight

AF131-018 TITLE: Digital Multispectral Binocular System (DMBS)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a helmet-mounted display (HMD) system for pilots that adaptively integrates shortwave infrared (SWIR), near-IR (NIR), visible, off-head thermal, and computer symbology/imagery into fused visualizations.

DESCRIPTION: Pilots need a visualization system that enables day/night/adverse weather operations and that is digital. Currently fielded night vision and day vision technologies are not integrated and do not work as well as needed under many illumination conditions. The opportunity now exists to replace two separate helmet clip-ons now in use–-the night-vision goggles (NVGs) based on analog technology (image intensifier vacuum tubes), and the day-target sighting systems based on analog microdisplays (high-voltage miniature cathode ray tubes (CRTs))—with a single integrated day/night/adverse weather visualization system based on digital devices (low-voltage digital solid-state imagers, processors, and displays). The goal of this topic is to create and develop revolutionary pilot HMD visualization systems via a spiral development process leveraging recent advances in imaging sensors, fusion algorithms, and supercomputing processors. New focal plane array (FPA) sensors with substantially improved visualization potential are now becoming available in several bands, including especially NIR & SWIR, but also visible, mid-wave infrared (MWIR) and long-wave infrared (LWIR, aka thermal, aka forward/downward-looking IR, FLIR/DLIR). Long-term efforts to develop scene-adaptive multiband image fusion algorithms have culminated in software available for implementation in a variety of warfighter visualization tasks to optimally combine two, three, or four different sensors of varying resolution. Supercomputing processors capable of 150 to 350 billion operations-per-second (GOPS) are becoming available to implement the advanced adaptive fusion algorithms in real time (30 to 60 Hz) in the form of either application-specific integrated circuit (ASIC) chips or one to two small boards populated with the latest floating-point-gate-array (FPGA) packages. All designs sought under this topic should be a binocular for an aviation helmet providing a 40º field of view (FOV) with 100 percent overlap and 1:1 magnification. The threshold (minimum) capability demonstration sought is a binocular HMD-mounted SWIR-only or SWIR-NIR system having a minimum resolution of 1280 by 1024 pixels with computer-input for either symbol overlay or synthetic/augmented image presentation to the eye. Objective long-term performance sought is 2560- by 2048-pixel image resolution, which corresponds to 20:20 visual acuity in a 40º FOV, in the final DMBS. Scene-adaptive fused imagery is desired in addition to the SWIR at all stages of DMBS development, including the possible addition of HMD-mounted visable sensors, or the use of aircraft-mounted imaging sensors in any portion of the electromagnetic (EM) spectrum--including LWIR, light detection and ranging (LIDAR), synthetic aperture radar (SAR)--to generate the fused image displayed to the eyes. All designs and prototypes should meet the space, weight, ergonomic, power, performance, and integration (SWEPPI) requirements for pilot helmet-mounted systems.

PHASE I:  Design binocular pilot HMD system sensitive in SWIR and VNIR (visible and NIR) with inputs for off-helmet symbology/imagery. Sensor may be a single FPA or multiple FPAs with electronic fusion. Display may be opaque or see-through. Processor must enable symbology overlay and fusion of a/c-mounted imaging sources.

PHASE II:  Fabricate binocular SWIR-VNIR pilot HMD clip-on system suitable for evaluation in a representative environment. Prototype must be demonstrated in a laboratory environment to enable symbol overlay and fusion of simulated a/c imaging sensors such as FLIR, SAR and synthetic vision. Prototype should meet the SWEPPI requirements for engineering development into a product for use with current helmets.

PHASE III:  Develop engineering prototype of helmet system and support flight test. Develop fusion helmet system and demonstrate in relevant environment. Develop commercialization plan to include applications to Homeland Security operations and civil aircraft operations in adverse weather conditions.

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1. Jeff Paul, "Exploit new spectral band (SWIR) & multi-spectral fusion: MANTIS Program Update," Multispectral Adaptive Networked Tactical Imaging System (MANTIS), WBR Soldier Technology US 2008 Conference (Worldwide Business Res. Ltd.,) Arlington, VA, 15 Jan 2008.

2. Goodrich, http://www.sensorsinc.com/whyswir.html for SWIR sensor data.

3. Peter Burt, "On Combining Color and Contrast-selective Methods for Fusion," IDGA Image Fusion Conference, Institute for Defense and Government Advancement, 2004.

4. Raytheon Vision Systems, http://www.raytheon.com/.

5. Wesley Sheridan, "Binocular Multispectral Adaptive Imaging System," Night Vision Summit, Institute for Defense and Government Advancement, 2010.

KEYWORDS: Pilot, binocular HMD, digital, multispectral, SWIR, NIR, adaptive image fusion, ASIC, MANTIS, synthetic vision

AF131-019 TITLE: Integrated Collaborative Mission Planning, Briefing and Debriefing Tools for Crews and Teams in LVC Operations

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To develop an integrated mission planning and analysis briefing and debriefing capability to improve operational training and rehearsal for teams and crews.

DESCRIPTION: This effort will develop a high fidelity and distributed mission planning, briefing and debriefing toolset for Live, Virtual and Constructive operations (LVC Ops). Most planning and evaluation systems currently in use rely on a significant human-in-the-loop component for developing the planning, for distributing planning and interactive mission developments, and for integrating a variety of after-action information for debriefing. To date, this manual process has not benefited from technological developments in on-line meeting management, collaborative tools for distributed team interaction and performance, and advances in digital performance measurement and data integration for mission evaluation and assessment. This severely limits the Warfighters' capability to modify and distribute mission data from Distributed Mission Training and live operational training events to all parties and players for instructional and research purposes. Considerable individual and team data, derived from the interaction and sharing of information, has been lost due to present limited online management capabilities. As we move into more distributed contexts, there is an increasing need to fully develop and exploit a range of hardware and software tools and technologies to manage on-line planning, training and evaluation activities. Such tools and technologies need to support instructional richness while also being operationally valid to facilitate mission planning and analysis in both training and operational contexts. Ultimately, this effort will demonstrate a fully distributed and electronically managed digital mission recording and playback capability for briefing and debriefing in crew and team mission areas. This effort also will provide an operational test-bed in which to explore collaborative, electronically-managed high-fidelity digital distribution of mission planning and mission outcome data to disparate locations. In addition, this effort will provide a means for the development of new electronic methods for structuring and visualizing the mission orientation and instructional quality of the mission planning, briefing and debriefing process for aircrews and more broadly battlestaff planners. Finally, this effort will directly evaluate the effectiveness of embedded collaboration and management methods, as well as on-line instructional strategies and decision support tools, within a crew briefing and debriefing context.

PHASE I: Develop specification of critical features & capabilities for local and long-haul collaborative briefing/debriefing for crews/teams. Identify & evaluate diverse approaches for managing collaborative mission planning, briefing, and debriefing. Based on evaluations develop proof-of-concept environment of key features and capabilities for usability evaluation prior to full development in Phase II.

PHASE II: Fully develop, refine, test and evaluate requirements for electronically managed mission planning, analysis & evaluation capability for local/non-co-located crews/teams. Include demo of integrated brief/debrief system with embedded mission planning, instructional features, and info management capabilities. Provide comparative data on training effectiveness and mission readiness enhancement prior to and after the implementation of the system in an operational AF context.

PHASE III: The tools and techniques have broad applicability to the commercial airlines community as a means of evaluating and assessing routing changes and flight planning modifications. The event management and collaboration tools to be developed will be of considerable interest to private sector business.

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1. Defense Modeling and Simulation Office homepage: www.dmso.mil.

2. Distributed interactive simulation systems for simulation and training in the aerospace environment. Proceedings of the Conference, Orlando, Fl, Apr 19-20, 1995. Clarke, T. L., ED. Society of Photo-Optical Instrumentation Engineers (Critical Reviews of Optical Science and Technology, vol. CR 58) 338p.

KEYWORDS: Air Combat tactics training and rehearsal, Brief and debrief systems, Distributed collaborative systems, Distributed Mission Training, Mission planning and analysis

AF131-020 TITLE: Curved Waveguide Visor Display (CWVD)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a curved transparent holographic optical waveguide visor for helmet-mounted display (HMD) applications that provides 100X more eye-movement freedom with 10X less space and weight of near-eye pieces.

DESCRIPTION: Recent developments in the fabrication of holographic waveguide optics systems make it possible to replace bulky, expensive, multi-element classical projection optics systems with light-weight, thin see-through diffractive optics. This effort is aimed at leveraging this optics revolution for next-generation aviation helmet visualization systems. The classical optics now in use result in excessive weight and bulk on the head and poor ergonomics, with massive helmet clip-ons for night or day vision being cantilevered in front of the eyes. Even so, the classical systems do NOT provide the high acuity and large fields-of-view desired by warfighters. Current HMD systems, such as the Joint Helmet Mounted Cueing System (JHMCS), are based on a bulky, expensive, large classical optics to relay a miniature display image to the eye via reflection off the inner surface of the helmet visor and produce a small FOV (e.g. 20-deg.), which requires much head scanning to maintain situational awareness, and a small eyebox (e.g. 9x9-mm), which requires custom helmet fit and may cause image loss during maneuver. A compounding problem is the need to address laser eye protection, where proposed solutions based on classical optics would add even more weight and bulk, making them non-solutions. "Optical magic" is needed to re-set the stage for a new generation of lightweight, yet more capable, HMD systems. Recent advances in holographic optics by researchers in several institutions have demonstrated the potential for the optical image magnification function to be implemented within thin waveguide structures. The potential exists to integrate the projection optics into the structure of the HMD visor itself, including curved visors. Threshold optical performance sought includes, simultaneously, binocular green HMD system with at least 1280x1024/eye (1.3 Mpx) resolution, a 40-deg. field-of-view (FOV), an eye box of over 30x30-mm, a pathway to color, and 10X less space, 5X less weight, and 2X less cost than current helmet projection optics. Power efficiency must be addressed and shown to be consistent with integration into a pilot HMD system. Objective performance includes a binocular color panoramic FOV of 120x80-deg with near 20/20 acuity (requires 5 Mpx for each 40-deg-cone of the FOV). This topic focuses on the design, prototyping, and demonstration of a curved, transparent holographic waveguide visor display (CWVD). The image generation device included in the design may be based on either a current or a proposed new technology.

PHASE I: Design a binocular CWVD system for a combat pilot HMD capable of presenting 1280x1024 monochrome imagery from a flat panel microdisplay in 40-deg. field-of-view (FOV) to the same quality as currently done with the micro-CRT and classical optics. Develop pathways to color.

PHASE II: Fabricate a day/night CWVD system that provides, at a minimum, binocular monochrome 1280x1024 imagery in a 40-deg. FOV on curved, transparent, holographic optical waveguides integrated into a visor. Demonstrate capability of waveguide to support higher resolution displays (5 Mpx in 40-deg FOV). Demonstrate viability of color.

PHASE III: Design product for military applications that replace classical optics in HMD systems with curved, thin, light, ergonomic diffractive optics. Design non-military products for homeland security for coastal and border patrol, aerial firefighting, highway patrol, and entertainment systems.

REFERENCES:
1. Paul Wisely et al., "Visor Display System," AFRL-HE-WP-TR-2006-0055 (April 2006). Distribution limited to US Government Agencies until 29 September 2009; abstract available. Direct requests to 711HPW/RHCV, WPAFB OH 45433.

2. Leon Eisen, Michael Meyklyar, Micael Golub, Asher A. Friesem, Ioseph Gurwich, and Victor Weiss, “Planar configuration for image projection,” Applied Optics, Volume 45, Issue 17, pp. 4005-4011 (10 June 2006), http://www.opticsinfobase.org/ao/abstract.cfm?&uri=ao-45-17-4005 (accessed 1 March 2009).

3. Alexander A. Cameron, "Displaying the Night--A Revolutionary Concept for Helmet Mounted Displays," Sheppard 2007 Night Vision Conference (30 October 2007); “The application of holographic optical waveguide technology to the Q-Sight family of helmet-mounted displays,” in Head- and Helmet-Mounted Displays XIV: Design and Applications, Proceedings of SPIE Volume 7326, Paper 7326-16 (16 April 2009), available from www.spie.org (in press).

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KEYWORDS: Curved Waveguide, Visor Display, Diffractive Optics, Large Eyebox, See-Through Near--Eye Display Optics, Helmet-Mounted Displays, HMD, Joint Helmet Mounted Cueing System, Laser Protection, Lightweight Day/Night Vision System

AF131-021 TITLE: Vision Processor for Helmet System (VPHS)

TECHNOLOGY AREAS: Information Systems, Sensors, Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: 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.

DESCRIPTION: Advances in digital sensors and digital displays now require the development of improved digital processing capacity that can be integrated within helmet space and mass limitations. The total head-born weight for helmet systems must be less than about 5 lbs including the shell, life-support, and any embedded electronics components (e.g. HMD system). The weight budget allocation to the helmet-mounted components of the HMD system is about 2 lb, including sensors, processors, microdisplays, optics, batteries, and cables. Also, the total power dissipation for the in-helmet components, which is dominated by the in-helmet processor and sensors, must be less than about 10 W to avoid the need for active in-helmet cooling. Prior approaches to the in-helmet processor required for digital all-source imaging have yet to meet these mass and power requirements. However, efforts to date have been based on older levels of microelectronics fabrication technology that are no longer state-of-the art: e.g. 90-nm design rule application specific integrated circuit (ASIC) or fifth-generation field programmable gate array (FPGA) devices. For example, the vision processor ASIC developed under the DARPA Multispectral Adaptive Networked Tactical Imaging System (MANTIS) program (2003-2010) 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. The final MANTIS program demonstration was a handheld system (no-helmet mounted components) with a processor that ingested three sensors (one each VNIR, SWIR, LWIR) and generated just one video output at 30 Hz. Binocular systems needed by pilots 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. Similarly, the FPGA approaches have not yet demonstrated the needed processing capacity in a sufficiently small form factor, but improved, sixth-generation components have now appeared. Hybrid processor architectures, e.g. an array of processing elements interspersed with memory routers on a single silicon chip, may also provide space and weight advantages over the more traditional ASIC and FPGA designs. The microelectronics design and fabrication industry serving companies that address applications such as VPHS has advanced beyond the 90 nm design rule to 45 nm, and will move to even smaller nodes (e.g. 22 nm). The performance metric for VPHS design pathways may be expressed as floating point giga-operations per second (GFLOPS) per Watt of power per gram of weight (GFLOPS/W/g). This metric increases as the silicon design node decreases. The 45 nm (22 nm) design node should be about 4X (16X) better (in terms of GFLOPS/W/g) than the 90 nm design node used in prior efforts and enable the performance needed in for digital HMD system designs.

PHASE I: Develop a plan to design and fabricate a VPHS. Perform an analysis of the proposed VPHS approach that demonstrates the capability to process the outputs of two 5-Mpx 14-b 96Hz sensor outputs through a representative set of imaging and display algorithms to drive two 5-Mpx 8-b 96Hz microdisplays with less than 1-frame latency. Estimate the power, weight, and size of the processor.

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. Estimate the power, weight, and size of the processor for both the threshold and objective performance levels.

PHASE III: Fabricate a prototype VPHS and demonstrate threshold (objective) capacity 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.

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KEYWORDS: Vision Processor, ASIC, FPGA, Acadia II, MicroCore, Virtex, HyperX processors

AF131-023 TITLE: Holographic Video Display (HVD)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop full-parallax solid-state 3D display with no moving parts, updated at video rates with electronically generated holograms, no special viewing apparatus, able to use streaming video and streaming geometry together with existing static content.

DESCRIPTION: Currently available true 3D displays have unacceptable levels of visual artifacts, do not provide full parallax, take too much power and space, require special headgear, create simulator-sickness effects in minutes, and preclude users from reaching into the image to control it. Additionally, they are unable to ingest and display fused realtime battlefield video and geometric information. Visualization of inherently 3D situations—such as deconfliction, line-of-sight analysis, air space, satellite constellations, terrain/building structures, and complex battlespace metadata—is significantly hampered when projected onto a 2D medium. Such presentations of 3D data on 2D displays is called 3D by the public, but is technically just 2.5D as it does not present all the 3D cues in the data to the viewer. The Air Operations Center Weapon System (AOC WS) currently presents static and video feeds on 2D displays. The static information incorporates Digital Terrain Elevation Data (DTED) and Distributed Common Ground System (DCGS) imagery on planning displays with video feeds from e.g. UAVs in separate windows. Streaming geometry 3D data from LIDAR and SAR is not currently available to operators, but is expected as the AOC modernizes - resulting in the need for processing, storage, and display technologies to fuse them with existing and emerging visual data feeds. For situational analysis and for ongoing operations, the ability to view the battlespace from any angle, using any data stream (video or geometry) is critical to effective decision making. Recent advances in microprocessors, algorithms, communications, and gesture control technology have now made it possible to develop a compact full parallax digital holographic display system with adequate performance for use in operational applications. Computational power to generate full parallax holograms can be produced affordably by use of clusters of computers and graphics rendering cards. The holographic element (sample of the 2-D hologram), should ideally be 500 nm or smaller in size and 14 bits in grayscale for adequate discrete representation. Alternatively, basis representations of holograms based on precomputed hologram element (hogel) basis sets require pixels of 10 µm or smaller compared to the 12 µm pitchs now in production for several microdisplay technologies. Nanoelectronics fabrication techniques now being matured by the integrated circuit industry at the 28-nm node, together with diffractive optics for pixel or hogel imaging, enable fabrication of hologram pixels (hpixel) across 100 sq inch of a 16-inch wafer. The resulting sampled hologram (~ 1 Tera-hpixels) might correspond to a true 3-D resolution of several megavoxels in a threshold 30º (objective 90º) field of view (FOV) once integrated in a suitable microoptics array. The goal of this topic is to enable attobyte command and control databases to be visualized and controlled dynamically in 3-D with look-around in all directions with artifacts that are acceptable by long-term use operators. Gesture control of the imagery is also envisioned to make user interaction with 3D content intuitive. Solid state 3-D would enhance both ground and airborne displays, providing depth information in the cockpit and reducing ambiguity in ground based applications. The technology developed in this topic must be scalable from individual/personal displays to multi-person/wall sized displays without significant sacrifices in power consumption or footprint. Prototype application focus for this topic is air, space, and cyberspace operations centers.

PHASE I: Design an HVD capable of presenting, at a minimum, a full parallax 1 Mpx color image at any pupil position in a 30-deg conical field-of-view at 30 Hz update rate (objective: 2 Mpx, color, 60-deg, 60 Hz) having a minimum of 10:1 contrast viewable in room illumination. Assess high speed video and geometry ingest, storage, and fusion technologies. Identify metrics for HVD. Develop an HVD roadmap.

PHASE II: Fabricate an HVD system capable of rendering and presenting computer generated holograms at video rate in a laboratory environment. Demonstrate real time fusion of live holographic video with static geometry (e.g. DTED), and imagery from local stores plus Open Geospatial Consortium (OGC) compliant services; updates to geometry using real time feeds; and texturing of both static and realtime geometry using both static and live video streams. Develop and apply HVD metrics to assess performance.

PHASE III: Military applications: Complex system visualization for air, space, and cyberspace situational awareness, planning, and execution of missions in command and control centers. Commercial application: Commercial air, computer-aided design, scientific and medical visualization, teaching, entertainment.

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KEYWORDS: Holographic Video Display, Full Parallax 3D, Light Field, Hogel, Voxel, Air Operations Center, Holography, LIDAR, SAR, Holographic TV

AF131-024 TITLE: Portable Sensor for Detecting Airborne Nanomaterials in an Operational Environment

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To design and develop a robust global positioning system (GPS) enabled, portable, and wearable sensor to evaluate key nanomaterial properties as a means of detection in an operational environment.

DESCRIPTION: Man-made nanomaterials (NMs) are being applied in many technologies, and the health risks associated with unintentional exposure remains a foremost concern of their pervasive use [1]. Numerous studies have been conducted to address the toxicity of NMs, and while the data is not conclusive, key relationships have been developed relating specific physicochemical properties of NMs with their toxicity [2,3]. Airborne NMs in an operational environment are not detectable without sensitive aerosol monitoring instruments, and even dilute concentrations can be linked to unwanted health effects. Without a means to detect airborne NM exposure, there is a potentially hazardous delay in implementation of preventative exposure protocols. Currently employed, continuous monitoring sensors to detect NMs rely on light scattering or mass recognition [4,5]. However, relying solely on these techniques does not allow for detection of key NM properties, which are related to their potential toxic effects, including surface area, morphology, composition, and impurities. Wearable filters for collecting airborne NMs are also available, but they do not provide any real-time data. There is an urgent requirement for a wearable personal sensor with the integrated capability to detect airborne NM concentration as a function of size and surface area, with efficient filter collection for additional laboratory analysis of morphology, composition, impurities, and toxicity.

The key phases of the project will include design of the principal concept for characterizing and collecting airborne NMs. The key requirements include the ability to (1) detect number concentration of NMs as a function of size, (2) measure surface area of particles, (3) capture NMs as a function of size and/or surface area on filters for further characterization, (4) record particle characterization, time, and location data that can be downloaded and displayed in a comprehensive manner. Incorporation of advanced features, including the ability to transmit data to a remote source in real-time will enhance the effectiveness of the wearable sensor. Additionally, convenience and aesthetics should be considered, as this is critical for proper and proficient use of the sensor. The impact of this technology is to enhance situational awareness for prevention of exposure and mitigation of potential health risks related to airborne NMs.

This technology will be useful for military applications such as identification of potential human risk due to NM exposure and pinpointing the location of the contaminant.

PHASE I: Design the concept and prototype for characterizing and collecting airborne NMs. The key requirements include the ability to (1) detect number concentration of NMs as a function of size, (2) measure surface area of particles counted, (3) capture NMs as a function of size on filters for further characterization.

PHASE II: Field studies will be conducted to validate the prototype upon successful design and creation.
Following prototype validation, develop a sensor incorporating (1) the ability to record particle characterization, time, and location data that can be downloaded into a program, and (2) the ability to transmit this data to a remote source in real-time. Additionally, design and integrate software in the sensor that, provides health risk information based on specific NM characteristics.

PHASE III: Functional portable sensor that would allow for the ability to detect the size and surface area of NMs in the environment and capture particles for more complex laboratory analysis, as well as transmit collected data in real-time to a remote source.

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KEYWORDS: global positioning system (GPS), nanomaterials (NMs), nanosensors

AF131-025 TITLE: Game-Based Tactical Training and Rehearsal Environment for Next Generation Multirole Fighters

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a high fidelity environment for next generation multirole aircraft tactical training and rehearsal.

DESCRIPTION: This effort will evaluate alternative approaches and will develop and demonstrate a lower-cost, high fidelity and deployable mission training and rehearsal environment for next generation multi role aircraft. One of the most difficult and critical activities associated with air combat today and tomorrow is realistically training for the advanced air to air and air to ground scenarios fifth generation tactical aircraft are expected to accomplish in the field. Today's high fidelity home station mission training center environments offer incredibly rich and realistic virtual and constructive training, but they are very expensive to own and operate and they cannot deploy with the operational units to allow for continuation training while at a non-home-station location. With continued flying hours reductions and the increasing fuel and sustainment costs associated with every airborne flying hour, constant deployments where home station training capabilities are not available, not to mention additional wear and tear or systems, there is a tremendous opportunity to develop and evaluate lower cost, more portable, and potentially as realistic, game-based environments as supplemental and complementary tactical training to live fly and high fidelity simulator training. The growing breadth and depth of game-based environments makes them plausible potential contributors to routinely accessible training rehearsal and exercise to support seasoning of operational crews. While game-based environments possess considerable flexibility and fidelity, these environments are not routinely viewed as plausible training and rehearsal environments. Game environments rarely (a) provide any mechanism for scenario design; (b) include support tools to deliver a single scenario or a group of scenarios as instructional events; (c) provide a means of systematic data collection on the players while in the game; and (d) warehouse event data for later after action review. With these issues in mind, this effort will evaluate alternative hardware and software (H/W S/W) solutions to developing lower-cost, credible and realistic training for fifth generation tactical air combat. It will also develop a high fidelity, game-based environment with methods and tools to permit instructionally valid individual and team training. The proposed environment will necessarily interoperate with virtual and constructive entities and will support a variety of tactical scenarios and missions.

PHASE I: Phase I will conduct a detailed mission analysis of relevant missions for multi role aircraft to identify content for the effort. Phase I will develop criteria and examine alternative hardware and software approaches and technologies for training supporting the missions and will develop specifications and a proof-of-concept training exemplar to be fully developed in the Phase II effort.

PHASE II: This phase II will prioritize missions for scenario and content development. Phase II will develop, refine, test and evaluate the full H/W S/W environment and its relevance for realistic integrated training and rehearsal for fifth generation tactical aircraft training at home station and in deployed contexts. Evaluations will quantify training effectiveness and mission readiness enhancement resulting from the environment. Training transfer potential to live fly exercises will also be assessed.

PHASE III: This effort has high commercial potential as both a game and training environment. Dual Use potential is significant for a flexible game based environment that can support a range of credible instructional scenarios and learner assessments and that is generalizable to other contexts.

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KEYWORDS: game-based training systems, high fidelity tactical training, tailorable training environments, performance based deployable training

AF131-026 TITLE: <u>Common Readiness Assessment and Performance Tracking, and Warehousing System for Day-to-Day LVC Training and Operations</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop on-demand methods for measuring assessing, formatting, predicting, and tracking readiness performance and proficiency data from live aircraft, instrumented ranges, and distributed mission operations simulation environments

DESCRIPTION: This effort will develop on-demand and predictive methods for assessing combat human performance and readiness within and across training and operational LVC contexts. While there are currently a number of commercial formats for human and system performance date available, the integration, routine assessment, prediction, readiness gap analysis, and resource allocation for various contexts available to improve readiness and proficiency has not yet been accomplished in a way that permits routine, on-demand, tagging tracking, warehousing and reporting on a consistent basis. Existing standards and capabilities in operation today, but they are not directly compatible with each other and it is currently impossible to share data from different environments/systems in order to assess human performance within and across them. The simulation community generally follows a Distributed Interactive Simulation (DIS) protocol or High Level Architecture (HLA). Live ranges use Test and Training Enabling Architecture (TENA) and exercises use systems such as the Nellis Air Combat Training System (NACTS). Each of these can provide data individually, but there is no integrated or systemic approach to cumulating the data, linking it to performance and readiness models and standards, assessing levels of understanding and knowledge from these data, or using the data to identify what is known and needed to be known so that subsequent training and rehearsal events can be identified, scheduled and executed. Moreover, a capability to routinely assess and track readiness and to predict future readiness or future training proficiency fall offs and sequences of initial and refresher training events based on performance at any given time does not exist today. With the merger of live, virtual, and constructive (LVC) systems, these incompatibilities represent a significant shortfall in our capacity to assess the payoff of integrated and joint training and exercise concepts like LVC as readiness solutions. Further, we cannot demonstrate the longitudinal impact of these concepts because we cannot routinely evaluate performance and readiness across training, exercise, test and evaluation contexts over time. To solve the shortfall, this effort will develop and demonstrate a method for capturing, storing, modeling and routinely reporting performance and readiness that is usable within and across live and virtual environments. A major part of this effort will examine existing data formats and structures within and across LVC environments and will develop and demonstrate capabilities to extract common data compatible across environments and systems. Representative data from the variety of potential sources will be provided as part of the effort start up. The successful effort will develop and demonstrate a comprehensive system that facilitates data collection, measurement, prediction, tracking, warehousing and modeling human performance for a variety of sources in a common format to permit sharing of common data for routine performance evaluation and management. Developing a common methodology and system combat readiness assessment, tracking, predicting, and reporting represents a unique and critical capability for the development, analysis - and most importantly - usability of performance indicators from different environments and systems optimizing LVC for future readiness and combat proficiency.

PHASE I: Phase I will identify and integrate exemplar metrics from different data formats and from live ranges, actual aircraft, and simulation-based systems into a proof-of-concept demonstration case and provide recommendations for portrayals of data, metrics, and models for predicting acquisition and mastery of combat knowledge in and across possible learning environments.

PHASE II: Will extend and elaborate the Phase I proof-of-concept to demonstrate common interfaces, extraction tools, data tagging, visualization, and reporting methods for the variety of data sources and formats identified in Phase I. The Phase II capability will also provide a demonstrable capability for data warehousing to permit routine measurement and tracking of performance "objects" across the relevant environments.

PHASE III: Common approaches for data integration/consolidation is a key need across military and civilian contexts. Existing systems are proprietary, limited in data availability and sharing, and are context specific. Example use cases are emergency operations centers and air and space operations centers.

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KEYWORDS: Developmental test and evaluation assessment, Training and rehearsal, Distributed mission operations, Distributed mission training, Performance measurement, Distributed Interactive Simulation (DIS),High Level Architecture (HLA),Live training

AF131-027 TITLE: Retrofittable Tactical Head Up Display (RTHUD)

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop an affordable, lightweight, very low profile, low power, and extremely high lifetime HUD using state-of-the-art (SoA) low cost digital projection technologies that can be retrofitted into tactical aircraft.

DESCRIPTION: The goal of this SBIR is to develop a competitive RTHUD design that will be extremely long lasting with a low life-cycle cost (LCC). The LCC is understood to include the total cost to procure, install, and maintain the RTHUD over the life of the air system. The threshold (objective) mean-time-between failure (MTBF) is 8,000 hrs (20,000 hrs). The threshold (objective) LCC is $150K ($75K). The design must contain a large wide area field-of-view (FOV) and require just 25% of the power, cooling, and volume consumed by SoA fielded HUDs. The RTHUD design should have novel volume and 3D shape features sufficient to enable affordable installation as a retrofit without extensive structural modification of the aircraft. The design should also enable installation in cockpit locations other than the traditional positioning within the forward field of view. The architecture should consider a solution approach that can be affordably installed by skilled artisans with minimal retrofit and/or assistance. The RTHUD solution shall be capable of being highly modular in nature and, thus, be able to very rapidly be installed to fielded jets with minimal rework. Design issues identified in MIL-HDBK-87213A (USAF) dated 8 Feb 2005, "DoD Handbook: Electronically / Optically Generated Airborne Displays," should be addressed for the operational environment representative of a tactical combat aircraft. The developed RTHUD system must be utilized to display the desired level of tactical HUD detail to operators in order to perform safely control the aircraft without outside assistance such as other displays. Threshold performance shall provide the same level of information that SoA fielded HUDs currently present to pilots. A balanced six-dimensionial systems engineering design is required: space, weight, ergnomics, power, performance, and integration (SWEPPI) issues all must be addressed. The RTHUD design should support the traditional HUD augmented reality (AR) mode of operation in which see-thru symbology focused at virtual infinity is superimposed on the highly-variable real world scene beyond the canopy. The design should also enable the RTHUD to operate as a non-see-thru, synthetic vision system (SVS) mode at night, during low-illumination day conditions, or when cockpit view is closed off by curtains against laser/flash threats. Advanced digital component technologies, including efficient solid state light sources, ultra-high resolution microdisplays, multispectral adaptive fusion processors, and compact waveguide optics should be considered to develop a high luminance/contrast day, night vision system compatible, design. Traditional combiner and image relay optics must be integrated into a more compact form than in any currently fielded HUD: refractive/reflective optics as well as diffractive waveguide optics approaches are sought to provide a threshold (objective) FoV of 40-deg (60-deg). The light engine and processor should be capable of generating a threshold (objective) image resolution of 5 Mpx (12 Mpx) to provide 50-arcsec acuity with acceptably low latency at the design eyepoint for all symbology and imagery presented.

PHASE I: The contractor shall perform a market technology sweep of current avionics HUDs, determine the ideal mix of SoA component technologies for incorporation in the RTHUD design proposed, present a complete system architecture of the envisioned solution to show each component will assist in achieving the capability desired, and perform a business case analysis of the proposed solution.

PHASE II: The contractor shall finalize the architecture development from phase I, develop and produce at least one prototype comprising both the hardware and software system(s) for testing and evaluation, test the capability of the prototype(s) to a basic preliminary level of confidence, demonstrate that the developed system can be utilized to display the desired level of relevant RTHUD detail, and update the Phase I business case and provide an estimate of installation and sustainment costs.

PHASE III: The contractor shall provide a preliminary plan of integration and conduct assessment cost feasibility to implement into target insertion point and complete bill of materials and team with an avionics integrator to identify and develop a safety of flight and full qualification plan.

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KEYWORDS: Head Up Display, HUD, Digital, Solid-State, Tactical, Enhanced Vision System, EVS, Synthetic Vision System, SVS, Helmet/Head Mounted Display System, HMDS

AF131-028 TITLE: A Text-Chat Based Natural Language Interface Toolkit

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Leverage results of synthetic teammate (intelligent agent) research to develop a text-chat based natural language interface toolkit that will facilitate the creation of constructive entities capable of functioning as teammates in training simulations.

DESCRIPTION: Text-chat based communications are becoming ever more common in Air Force operations environments—especially Unmanned Aerial Vehicle (UAV) and Air and Space Operations Center (AOC) operations. To support the training of airmen in these environments, training simulations need to incorporate constructive entities functioning as synthetic teammates (intelligent agents) which are capable of text-chat based communications with human teammates who are being trained. To facilitate the development of language capable constructive entities, a Natural Language Interface (NLI) toolkit which leverages prior synthetic teammate research (Ball et al., 2010, Rodgers et al., 2011, in press) is needed. Starting with a language capable synthetic teammate developed for a specific domain (Ball et al., 2010), extract out generalizable elements and use the generalizable elements as the basis for creation of an NLI toolkit that facilitates development of language capable constructive entities for other domains. Key technologies to be leveraged include state of the art language analysis (Ball, 2011), situation modeling (Rodgers, et al., 2011; in press) and language generation capabilities. It is not expected that existing synthetic teammate technologies will be entirely sufficient for research and development of the NLI toolkit. An important part of the research will include the identification of technological gaps, and research and development of solutions to close the identified technological gaps. Adoption of state-of-the-art computational linguistic techniques to fill identified gaps may be necessary. For an assessment of the current state-of-the-art in computational linguistics, see Jurafsky & Martin (2009), or Cole et al. (1997). These resources identify the basic computational techniques and machine learning mechanisms that are currently being used. The synthetic teammate research diverges from prevailing computational linguistic approaches in adhering to well-established cognitive constraints on human language processing. Competing computational linguistic approaches make no commitment to cognitive plausibility, relying instead on the use of advanced computational techniques and statistical machine learning methods which are typically not cognitively plausible. Determining how to integrate such techniques to fill gaps in the synthetic teammate research without sacrificing overall cognitive plausibility will be an important research topic. Key components of the NLI toolkit are likely to include: 1) An installation script for rapid installation of the NLI toolkit software, 2) a GUI/programmatic interface that supports the creation of NL interfaces, using synthetic teammate technology in the background, 3) a communications interface for integrating NL interfaces created with the toolkit into training simulations. It is expected that the NL interface will run in a separate process from the training simulation. The NL interface will also need to interface with additional software that performs the task associated with the role of the constructive entity (e.g. pilot, navigator, sensor operator, intelligence analyst), 4) tools for expanding linguistic and world knowledge, and 5) tools to support creation of domain specific knowledge. To demonstrate the capabilities of the NLI toolkit, the NLI toolkit will be used to develop a language capable constructive entity. After development, the constructive entity will be functionally validated in an AF relevant training simulation that involves communication with human teammates.

PHASE I: Determine the requirements for creation of a text-chat based NLI toolkit which leverages synthetic teammate technology; identify gaps in the existing technology and propose solutions for closing the gaps; and document the results in a technical report.

PHASE II: Research and develop a Natural Language Interface (NLI) toolkit which leverages synthetic teammate technology, identifies gaps in existing technology and provides solutions to fill the gaps. Develop a language capable constructive entity using the NLI toolkit, and demonstrate and validate the use of the constructive entity in an AF-relevant training simulation. Generate a technical report documenting the results.

PHASE III: Military applications include creation of language capable constructive entities for training and simulation. Commercial applications include training & simulation, as well as many other applications which require a text-chat based NLI.

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KEYWORDS: Natural Language Interface toolkit, Constructive Entity, Synthetic Teammate, Language Capable, Text-Chat Communication and Messaging

AF131-029 TITLE: Efficient Model Posing and Morphing Software

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop an efficient software approach to manipulate the pose and morph the shape of voxelized anatomical models. These models are high-fidelity (mm resolution) representations of the tissue and organ layout within the body.

DESCRIPTION: Electromagnetic devices are used increasingly in society, with applications in communication, medicine, security, and defense, among other disciplines and technology areas. This has led to a great deal of research regarding the safety and potential health hazards of such devices. To aid in this study, several high-fidelity voxelized anatomical body models have been created. These voxel models can be used in conjunction with sophisticated computational electromagnetic (EM) and thermal solvers to address the energy absorption rates and temperature increases expected within tissue due to radio frequency (RF) exposures.

Recently, researchers have created extremely efficient EM and thermal solvers through hardware acceleration or approximation techniques. These software approaches allow researchers to quickly simulate (within minutes) the energy absorption and temperature increases within tissue for a single anatomical model. However, simulation results reported in the scientific literature indicate that the posture of an individual within an incident RF field has a significant effect on model predictions, as does the anatomical geometry. Since voxel models are costly to create, and available postures are limited by the imaging modality used in their generation (typically MRI), research has focused on posture manipulating and morphing software to address this limitation. However, the reposing and morphing software created to date requires up to many hours of computational runtime to achieve a single new voxel model, clearly forming a bottleneck for RF dosimetry studies in comparison to the ultrafast EM and thermal solvers.

Therefore, there is a need for the development of highly efficient software to 1) manipulate the pose of voxelized anatomical models and 2) morph anatomical models according to various anthropometric parameters. The ideal solution should require on the order of minutes or less for the generation of a newly posed or morphed anatomical model. Approaches to the posture manipulation component of this work should allow for realistic manipulation of joints, and seek to conserve mass and dielectric continuity for both bones and associated soft tissues in the vicinity of joints. Additionally, incorporating human motion-capture data would be highly desirable in order to both automate model postures (walking, sitting, etc.) and to ensure high biofidelity. For example, data from the biomechanics research field in general can be utilized to ensure model postures accurately reflect real-life human body postures. Specifically, 3D Anthropometric databases may be useful for obtaining the external dimensions of humans in various poses.

Approaches to the model morphing portion of this work should allow models to be morphed according to certain anthropometric parameters (e.g., height, body fat percentage, BMI). Additionally, techniques to allow higher-fidelity partitioning of organs of interest (e.g., re-meshing the brain to differentiate regions) are desirable.

Biomedical scientists, health and medical physicists, and bioenvironmental engineers would all benefit from software that enabled efficient voxel model reposing and morphing. Additionally, the techniques developed could be very useful within a surgery planning tool.

PHASE I: Determine the computational methods to be used, and develop prototype software that illustrates the effectiveness of the algorithms chosen for both reposing and morphing existing anatomical models. The software may manipulate the models directly as voxel descriptions, or through more advanced boundary representation formats. However, the software output should be converted to a voxel format.

PHASE II: Extend the software created in Phase I to be fully developed and optimized with respect to computational runtime. A user interface should be included for manipulating the anatomical models and viewing the output. Where appropriate, metrics should be determined and utilized to verify the software output (e.g., conservation of mass). Preferably, the software should be able to manipulate the anatomy and output voxel models at 1 mm or finer resolution.

PHASE III: Use by engineers and health physicists to study risks of accidental RF overexposures over a broad set of exposure conditions. Used by Air Force to predict potential of overexposure during engagement of novel directed energy systems.

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KEYWORDS: morph, voxelized, electromagnetic (EM), radio frequency (RF), anatomical model, biomechanics

AF131-030 TITLE: Volatile Organic Compound Odor Signature Modeling

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Research and develop methods, models and algorithms for use in portable sensing platforms to predict the transport and dispersion of volatile organic compounds (VOCs) emitted from individuals of interest and their related threat activities.

DESCRIPTION: Background & Significance – A growing body of discoveries in molecular signatures have revealed that VOCs, the small molecules associated with an individual's odor and breath, may be monitored to reveal the identity and presence of a unique individual as well as an indicator of certain activities. Animals use VOC recognition to distinguish between friend, foe, or prey. Dogs can recognize specific odors related to some disease states. Medical practitioners can also recognize characteristic odors of certain disease states, i.e., ketosis. The ability to find and track individuals using VOC signatures would greatly enhance DoD capability to defeat asymmetric threats. These individuals often hide in civilian populations emerging only to strike warfighters and then retreat behind their civilian shield. Current policy requires our forces to avoid inflicting collateral damage on innocent civilians. As such, it is necessary to improve our ability to identify and track individuals and their threat activities. The ability of animals to identify and track individuals using scent has led to an interest in developing a similar signals intelligence capability. As highlighted in a review article by our group (Kramer, R., Grigsby, C., 2012), recent research in odor-based sensing has shown that this technology provides a means whereby individuals and their threat activities may be identified through unique combinations of VOCs emitted by the body. Development of the capability to predict the transport and dispersion of VOCs in both interior spaces and the environment will assist in defining the technical requirements and operational application of VOC-based sensors with the goal of the generation of a "reverse" modeling capability to backtrack individuals and activities of interest.

The current state-of-the-art requires an informant or another person to be physically close to the person of interest to positively identify him. Physical disguises may often make identification of individuals very difficult. The use of VOC signature data to identify a person of interest has potential to overcome any physical disguises and the need to put friendly forces at risk by being in close proximity in hostile territories.

The hypothesis is that operational environment transport and dispersion modeling of human-emitted VOCs may be used to provide a temporal characterization for an individual's presence at a specific location. This is supported by the fact that volatile organic compound signatures have been proven capable of identifying unique individuals. Further, modeling and simulation of the VOC transport and dispersion process may be employed to support this research hypothesis.

PHASE I: Successful completion of Phase I will require empirically derived physical characteristics for a minimum of twelve specified VOCs, evaluation of potential atmospheric chemical breakdown/reactivity, and development of transport and dispersion (T&D) models of the supplied VOC pattern in both interior spaces and the environment.

PHASE II: Research, analyze, and define volatile organic compound sensitivity and specify sensing requirements for hand-held detection, using both single point, enhanced "E-nose" type detection as well as multiple detectors. Research and develop models and algorithms to backtrack an individual's past location. This phase will culminate with transition of algorithms and models into a platform independent language for integration into portable sensor device prototypes.

PHASE III: Successful commercialization of this research will require incorporation of the developed models and algorithms, i.e., empirically derived VOC characteristics and developed inverse modeling capability for back-tracking the VOC source spatially and temporally, into a supplied prototype sensing platform.

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KEYWORDS: Mass transport, volatile organic compounds, vapor pressure, chemical reactivity/degradation, chemical diffusion, plume and inverse modeling

AF131-031 TITLE: Derivation of Physiologic, Neurophysiologic, and Behavioral Indices to Support Real-time Assessment and Augmentation of Team Performance within the Cyber Domain

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Development of a solution which provides real-time objective measurement and assessment of team functional states through advanced behavioral, neurophysiological, and physiological signal processing and data modeling.

DESCRIPTION: The DoD is currently engaged in full-spectrum cyber operations that place enormous demands on the technological systems and human operators tasked with this mission. As the cyber threat continues to grow, additional task loading will necessitate methods of performance augmentation to ensure mission success. Full spectrum cyber operations can be divided into two main categories: Cyber Network Attack (CNA) and Cyber Network Defense (CND). Cyber Network Defense (CND) refers to the constant monitoring and defense against possible and emerging cyber threats. Conversely, Cyber Network Attack (CNA) is a coordinated effort to achieve operational results that may reside specifically in the Cyber domain or could involve traditional kinetic operations. Regardless of whether an operator or team is faced with CND or CNA tasks, day-to-day operations within the Cyber domain require significant multi-tasking and a keen contextual awareness of the constantly changing environment.

Knowledge and understanding of real-time and historical changes in team states are necessary so that appropriate augmentation strategies can be executed in real-time to optimize team performance. Team performance measures include the time to identify cyber opportunities and/or threats and employ exploitation measures to gain an advantage. Studies based out of the Air Force Research Laboratory (AFRL) have indicated that synchronicity in both behavioral and physiological/neurophysiological responses may provide significant benefits and enhancement of individual operator and team performance. [1-4] Research in the Air Traffic Control (ATC) and Remotely Piloted

Aircraft (RPA) domains has surrounded the signal processing and modeling of physiological and neurophysiological data in order to support classification of operator cognitive state.[2,3] The major goal of this research is the development of adaptive aiding strategies which will avoid unwanted and potentially catastrophic performance decrements. [4] Similar research is needed within the Cyber domain where operators and teams must be vigilant at all times in order to recognize both emerging threats and provide timely and effective defense against them and identify opportunities for targeted attack. An effective solution would be one which is adaptable within the ever-changing complexity of the Cyber domain.

PHASE I: Generate a conceptual framework to demonstrate the initial feasibility of a fully integrated and deployable system capable of real-time assessment and augmentation of team performance within the Cyber domain. Integrate real-time processing and modeling of pertinent physiological, neurophysiological, and behavioral data.

PHASE II: Collect data to validate the measurement, assessment, and augmentation capabilities of the system in representative settings. Expand the system's capabilities to adapt across different cyber-team scenarios, i.e., CNA and CND. Demonstrate real-time assessment and augmentation capabilities of the developed system. Develop appropriate visualization and data play-back options to support use within the cyber-intelligence operational setting.

PHASE III: Transition the system within real-world operational environments and demonstrate the functionality, reliability, and usability. Ensure system design is adaptable to changes in the technological and structural hierarchy of the cyber-intelligence domain.

REFERENCES:
1. Strang A., Funke G.J., Knott B.A., & Warm J.S. (2011) Physio-behavioral synchronicity as an index of processes supporting team performance Proceedings of the Human Factors and Ergonomics Society Annual Meeting 55, 1447-1451.

2. Wilson, G. F., & Russell, C. A. (2003). Operator functional state classification psychophysiological features in an air traffic control task. Human Factors: The Journal of the Human Factors and Ergonomics Society, 45(3), 381-389.

3. Wilson, G. F., & Russell, C. A. (2003). Real-time assessment of mental psychophysiological measures and artificial neural networks. Human Factors: The Journal of the Human Factors and Ergonomics Society, 45(4), 635-644.

4. Wilson, G. F., & Russell, C. A. (2007). Performance enhancement in an uninhabited task using psychophysiologically determined adaptive aiding. Human Factors: The Journal of the Human Factors and Ergonomics Society, 49(6), 1005-1018.

5. Human Factors and Ergonomics Society (HFES) Copyright Transfer Form.
(Uploaded in SITIS 12/14/12).

KEYWORDS: cyber operations, neuroergonomics, psychophysiology, team cognition

AF131-033 TITLE: Cloud Based Secure Handhelds for Missions requiring Mobility

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Securely connect mobile computing hardware to appropriate commercial and DoD/IC networks while maintaining data separation and commercial functionality.

DESCRIPTION: DoD and IC users have come to expect one level of access to information via mobile technology at home and another, reduced level while on the job. While there are many valid reasons for this, specifically including restrictions on the access of classified material among others, it is potentially possible to reduce this gap by creating the ability for trustworthy ‘compartments’ within mobile devices to securely connect with appropriate infrastructure.

Many parts needed to solve this challenge already exist. Examples of ways to improve assurance of the mobile endpoint include the Trusted Platform Monitor, NSA’s SE Android and Citrix’ XenClient XT, among many others. The first two options and their analogues could allow for the endpoint to launch applications in an extremely tamper-resistant manner, while the last option along with other hypervisor or separation kernels can also help provide trustworthy compartments to prevent inappropriate information sharing. Commercially available endpoints (cell phones, tablets, etc) provide multiple standardized ways to communicate with international infrastructure (3G/4G, WiFi, etc) as well as a large number of sensors (accelerometers, cameras, touch screen, microphone, etc), ever growing capacity to transmit, receive, store and process information and given their commercial acceptance & growth they provide the users with a general comfort level while utilizing their functionality.

What does not yet exist is secure attestation of system state regardless of which one of multiple ‘compartments’ are attempting to connect to appropriate remote services, be these cloud-based or otherwise. The ability to ensure only trustworthy processes are running on a mobile endpoint, enabled from a known good hardware and software state, regardless of separation into ‘compartments’ or not, is a very important portion of the end-to-end connections needed. This works well today within a single ‘compartment’, but the difficulties in any single compartment initiating the communications (as per several normal modes of operation of mobile commercial systems) have yet to be conquered.

Thus this SBIR is intended to provide a prototype and method for secure attestation to remote assets regardless of which ‘compartment’ on the mobile device initiates or receives the connection request. These attestations may be up to (but may not be limited to) some “measured launch environment” (MLE), in order to provide assurance that the underlying system maintains its trusted state. While ideally this would work regardless of the number or type of ‘compartments’, it may be necessary to limit this breadth to some lesser scope. If so, justification of these limitations will need to be accomplished. Similarly, ideally this would not require any hardware modification of commercially available mobile endpoints (cell phones, tablets, etc). If there are necessary limitations, identifying and justifying those limits will be needed. Ideally, full commercially available functionality will also be preferred, but justified limitations may be acceptable.

The resultant prototype must have detailed plans to be extensible to cover NIST SP 800-53 security controls as selected from the UCDMO Cross Domain Solutions Overlay (CDSO), as well as the guidance and requirements made available via the “Commercial for Classified” effort and Mobility Program sites from NSA (links below, Intelink-U account required for UCDMO CDSO). Any further limitations along similar lines to meet these security requirements will need to be identified and appropriately justified.

PHASE I: Identify and detail a multi-compartment secure attestation of system state using commercial hardware & software as described above. Reuse existing capabilities where practical, or justify where impractical. Analyze security risks associated with these choices and identify options to mitigate them. The proposed system design must meet or exceed appropriate security controls as identified.

PHASE II: Create a limited prototype product to implement the security design chosen. Include development of security relevant documentation covering concept of operations, a cross-referenced test plan for functional & security requirements, and test results. Demonstrate performance, functionality and security of the prototype. Identify and partner with one or more operational customer(s) for further development and productization.

PHASE III: With an operational customer submit product for certification & accreditation. Simultaneously offer the product(s) to commercial vendors for use in high-assurance roles (healthcare, financial market, personal finances, etc).

REFERENCES:

1. Unified Cross Domain Management Office's Cross Domain Solutions Overlay, https://www.intelink.gov/sites/ucdmo/Docs/Documents/CDS_Overlay%20V1.docx

2. NSA Commercial Solutions for Classified site: http://www.nsa.gov/ia/programs/csfc_program/index.shtml.

3. NSA Mobility Program http://www.nsa.gov/ia/programs/mobility_program/index.shtml.

4. XenClient XT product page: http://www.citrix.com/English/ps2/products/subfeature.asp?contentID=2315434.

5. SELinux Project wiki page on SE Android: http://selinuxproject.org/page/SEAndroid.

KEYWORDS: Remote attestation, mobile security, secure mobile platform, mobile data sharing in contested environments

AF131-034 TITLE: Proximity-Based Access Control

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a standards-based access control mechanism that will dynamically adjust data access for individuals based on their proximity to others/organizations in terms of attributes (e.g. location, mission, assignment) derived from existing sources.

DESCRIPTION: Warfighters need access to a wide range of data from sources throughout the battlespace, and data requirements are only growing as our forces become more distributed, the tempo of operations increase, and units join in more ad hoc relationships. Nevertheless, warfighters have finite time and attention to find, access and consume data. Although the DoD has embraced Attribute/Role Based Access Control (ABAC/RBAC) approaches [1] through Unified Authorization and Attribute Services (UAAS) [2,3], many questions and specific details remain and programs/commands are hesitant to share on an ad hoc basis for both security (e.g., insider threat) and resourcing (e.g., limited system capacity, limited administrative capability) reasons. As a result, warfighter needs for agile information are not well balanced with their limited time and attention, and the enterprise's need for security.

This topic is for the development of a Proximity-Based Access Control mechanism that will dynamically adjust data access for individuals based on proximity profiles.

Generally, the closer something/someone is in proximity to a warfighter, the more important it is to that person and the more details the warfighter will need about it. This is true whether we are talking about spatial proximity (i.e., physical location), organizational proximity (e.g., relationships in the chain of command), or operational proximity (e.g., supported/supporting units, common missions). This observation allows us to begin to infer the "need-to-know" states of individuals that benefit both data providers and consumers.

For instance, it is easy to imagine that a squadron commander may want to gain insight into data from other units at a shared airfield (spatial proximity) in order to increase logistical efficiencies, better understand what sister squadrons (organizational proximity) are doing in order to coordinate better, or delve into the details of an intelligence assessment developed by a supported ground unit (operational proximity) in order to plan more effectively. Today, however, these three simple examples are difficult to accomplish without a high degree of personal attention, and time – both of which are in very short supply on today's battlefields.

By utilizing proximity-based data profiles, we can anticipate and serve many warfighter data needs dynamically while taking a risk management approach to providing access. Moreover, we expect that types of proximity can be inferred by looking at existing data and approaches (e.g., The DoD "13+2" attributes used for Attribute Based Access Control's, physical location, command relationships, organization for combat, missions).

The impact of this capability could potentially be very large as it could automatically increase access for those with a valid need-to-know, while decreasing the "all or nothing" system-wide access that has caused insider threat issues in the past (e.g., the case of Pvt Bradley Manning releasing classified information in 2010). It would also be more easy to monitor and audit access than is currently possible. Additionally, it has implications for aiding users in focusing their attention by inferring what might be useful based on the proximity profile. That is, beyond inferring a need-to-know based on proximity, we might also be able to infer those things that will be of the greatest importance at any given time – a useful side benefit in a highly dynamic environment.

PHASE I: Investigate the state of the art for RBAC/ABAC. Explore data sources to calculate proximity profiles. Evaluate methods for calculating proximity profiles from available data and applicable standards for implementation. Test the efficacy and efficiency of providing proximity-based access control. Evaluate the ability to adhere to the UAAS approach and standards.

PHASE II: Develop prototype software to demonstrate and test the feasibility and effects of proximity-based access control. Demonstrate and assess the ability to integrate (or make interoperable) proximity-based access control by creating a Service Oriented Architecture (SOA) service that may act as a new pluggable access control layer for legacy systems.

PHASE III:
Military Application: Direct application in an exercise environment to validate the concept and application.
Commercial Application: Direct application in providing access dynamically.

REFERENCES:
1. R. Sandhu, E. Coyne, H. Feinstein, and C. Youman. "Role-Based Access Control Models". IEEE Computer (IEEE Press) 29 (2): 38–47. August 1996.

2. Authorization and Attribute Services Tiger Team. “Department of Defense and Intelligence Community Unified Authorization and Attribute Service: Policy Recommendations”. September 2008.

3. PEO-C2C. “Joint Command and Control Objective Architecture: Information Assurance View”. Draft 2.0, October 2010.

KEYWORDS: access, control, ABAC, RBAC, proximity, data, profile

AF131-036 TITLE: Militarized Airborne Very Low Frequency (VLF) Receive Antenna

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Design a new militarized airborne Very Low frequency VLF receive antenna with high sensitivity and rejection of aircraft Electromagnetic Interference (EMI).

DESCRIPTION: A new VLF receive antenna technology is needed. The design will receive low signal to noise ratio VLF energy in the 14-60KHz band, through all phases of conflict in the harsh Nuclear Command Control and Communications (NC3) environment (shock, vibration, nuclear hardening). The new design will also guard against aircraft EMI that can saturate the antenna core, while minimizing size, weight, and power. The antenna design may consider multiple polarization axes to support anti-jam functions and more robust rejection of polarized EMI. Commercial laboratory grade magnetometers, which have some of the desired performance characteristics, currently exist. These magnetometers have been shown to function favorably in at least a subset of conditions a fully operational USAF VLF antenna will experience. What does not yet exist is a militarized antenna designed for USAF airborne use in a VLF receive system designed for the harsh NC3 environment (including nuclear scintillated atmosphere, jamming sources, and long distance reception). This topic does not exclude other parts of the VLF receiver system. It can begin with the militarized VLF receiving antenna, but also could include the front end electronics that interface the raw antenna signal with the receiver's signal processing subsystems. Simply designing the antenna may be too simple; designing the whole VLF receive system may be too complex for SBIR. However, a new VLF antenna technology that includes the first electronic steps in the receiver message processing may be an appropriate scope. Currently, USAF and USN are considering full replacements or modern upgrades of their fielded VLF receivers. The output of these research projects would have direct application in the next few years.

PHASE I: Design or simulate a VLF receive antenna with high sensitivity and rejection of aircraft EMI.

PHASE II: Build upon the work in Phase I by demonstrating the VLF receive antenna.

PHASE III: Military application: VLF transmitter receive antenna with high sensitivity and rejection of aircraft EMI. Implement product from Phase II with Air Force NC2 terminal programs to meet user need.

REFERENCES:
1. Engineering Village 2 - VLF communication system. Wheeler, Myron S. Assignee: Westinghouse Electric Corp. Publication Number: US4903036 Publication date: 02/20/1990 Kind: Utility Patent Grant

2. IEEE Xplore - Millen, E.; "A comparison of loop antennas," Electromagnetic Compatibility, 1990. Symposium Record., 1990 IEEE International Symposium on , vol., no., pp.451-455, 21-23 Aug 1990

3. EBSCO MasterFILE Premier - Chevalier, Timothy W., Umran S. Inan, and Timothy F. Bell. "Terminal Impedance And Antenna Current Distribution Of A VLF Electric Dipole In The Inner Magnetosphere." IEEE Transactions On Antennas & Propagation 56.8 (2008): 2454-2468.

4. The Nuclear Matters Handbook - http://www.acq.osd.mil/ncbdp/nm/nm_book_5_11/index.htm.

5. VLF receive antenna example specifications, uploaded in SITIS 12/18/12.

KEYWORDS: VLF, LF, NC3, EMI

AF131-038 TITLE: Validation of Automatic Ground Moving Target Indicator Exploitation Algorithms

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a cost effective method to provide independent validation of automated Ground Moving Target Indication (GMTI) exploitation algorithm performance.

DESCRIPTION: Ground Moving Target Indicator (GMTI) data has proved to be a valuable tool for the warfighter. GMTI data provides an indication of ground target movement, as well as the direction of that movement and an estimate on target size. GMTI data can be collected over extremely large areas of interest, with high update rates, and provides all weather, day and night coverage. Exploitation data products include force protection, detection of traffic in restricted areas or near an installation of interest, link analysis, patterns of life discovery, and milling activity.

The current volume of GMTI sensor data is too large for the analyst community to fully exploit, and data volumes will only grow as new sensors are deployed. Proper exploitation of GMTI data requires a higher degree of training than for exploitation of other common ISR INTs, therefore GMTI data exploitation is severely limited by the availability of trained personnel. Development of high quality automated GMTI data exploitation systems is essential in order to extract the full intelligence benefit from current and future GMTI systems.

Many research groups are actively developing algorithms and tools for automatic exploitation of GMTI data in answer to this need. These tools are designed to provide a variety of data products, including target tracks and indications of specific target behaviors. Generally, GMTI exploitation algorithms have only limited testing at best, due to the prohibitive cost of running live sensor experiments, and the limited number of data sets for which ground truth has been collected. Analyst acceptance of exploitation algorithms is hampered by the lack of verified metrics quantifying the probability that exploitation data products are correct. GMTI data analysts will only accept automated exploitation systems if they feel confident that the systems are providing accurate intelligence. Without this confidence, tools are not adopted, and data exploitation suffers.

This solicitation is for the development of a GMTI exploitation algorithm validation capability that will ensure that efforts to bring exploitation tools to the war fighter provide high quality, high confidence data products. The successful proposal will provide a statistically significant validation framework within reasonable cost constraints. This framework will be able to accommodate validation of a diverse set of exploitation algorithms goals, to include target tracking and detection of milling activity and other GMTI exploitation data products. Potential non-Government applications of this framework include validation of traffic modeling and site security techniques and algorithms.

The Government will provide data as needed for the development; simulated unclassified data if required for Phase I and real GMTI data for Phase II and beyond.

PHASE I: Develop a low-cost and statistically rigorous approach to GMTI exploitation algorithm validation. This approach should be applicable to general GMTI sensor systems and flexible enough to be useful for different exploitation goals. Describe how the methodology will be used to evaluate data exploitation algorithms created by third party developers, including interfaces and software dependencies.

PHASE II: Based on the techniques demonstrated in phase I, develop a GMTI exploitation algorithm validation framework which provides statistically rigorous and unbiased analysis of candidate exploitation algorithms. Demonstrate proof-of-concept of this validation approach by applying it to government supplied data and algorithms in order to evaluate those algorithms for probability of correctly extracting information data products. Provide documentation of system ICDs and basic user's manual.

PHASE III: Transition validation tool to government system(s), provide training in tool functionality to increase analyst acceptance of the validation methodology and tool adoption. Provide instantiations of the tool and test data sets to algorithm developers for early Q&A of automated exploitation tools.

REFERENCES:
1. United States Air Force Chief Scientist (AF/ST) Report on Technology Horizons Volume 1, AF/ST-TR-10-01-PR, 15 May 2010.

2. Fundamentals of Radar Signal Processing, Mark A. Richards, McGraw-Hill.

KEYWORDS: GMTI, Radar, Exploitation, Automation, Sensors, ISR

AF131-039 TITLE: Geographically-Aware and Targeted Secure Information Dissemination (GATSID)

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of

foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a product enabling on-the-move warfighters to securely send and receive information that can be targeted and tailored for sender-specified geographic regions to rapidly react to changing battlefield conditions and deliver battlefield alerts.

DESCRIPTION: The goal of the research and development effort is to build and demonstrate a software product called Geographically-Aware and Targeted Secure Information Dissemination (GATSID). GATSID will enable on-the-move warfighters, equipped with state-of-the-art wireless information appliances (e.g., handheld, commercially-available or militarized, or wearable computers), to securely send and receive information that can be targeted and tailored for sender-specified geographic regions, sectors, or operating areas. GATSID will enable mobile warfighters to rapidly react to changing battlefield conditions by delivering location-specific time-critical battlefield alerts and advisories.

It will implement the following capabilities:
1. A geographically targeted information multicast service that enables an application to securely send data directed at mobile appliances situated within a specified geographic area. The area may be specified graphically (e.g., on a mapping display) or by identification label or geographic coordinates. A minimum of one point with operating radius or two or more points to define outer bounds of the affected area.
2. Range-restricted information dissemination service that delivers data securely to eligible mobile appliances within a given range (say 2 kms) of the information disseminator, where the latter could be a mobile wireless appliance itself.
3. "Banner in the Sky" service that allows information to be “posted” within a specified geographic region. The posted information is then delivered securely to any eligible fixed or mobile appliance entering the region.
4. Adaptation and customization of delivered information based on user’s profile, user’s device, and wireless link capacity.

In the GATSID concept, the mobile warfighters are equipped with wireless information appliances such as smart phones that support two capabilities: 1) a position location mechanism (e.g., a Global Positioning Satellite [GPS]); and 2) an (Internet Protocol) IP-based wireless interface for connectivity to the military Internet. All communication to and from the mobile appliances is thus accomplished over IP. A non-GPS-equipped device may be referenced for another known GPS-equipped device(s).

GATSID will address a major aspect of the challenge of delivering “On-demand Information: "What you need …. When you need it”. It will enable future situational awareness systems where intelligence and tactical sensor data must be exploited to provide customized, location-specific information to the force. The following paragraphs present example scenarios to illustrate the application of GATSID:

Example 1: An unmanned aerial vehicle (UAV) operator performing a reconnaissance mission notices what appears to be a suspicious enemy activity in an area where Special Operations Forces (SOF) operations are ongoing. The pilot can use GATSID to send a targeted warning or alert message to all SOF warfighters in the vicinity of the threat. These warfighters will immediately receive this alert on their mobile appliances and can take necessary actions to counter the threat.

Example 2: A first responder to an emergency uses his or her handheld device to broadcast a call for help to medical response teams within a 5 mile radius around the site. All medical response teams receiving the message can respond back with the ones closest to the site directed to proceed to the emergency scene.

PHASE I: Define, determine feasibility and demonstrate a means to collect and identify potential receiving nodes by class, location, or other means. Provide approach to capture the addresses (all modes) of identified receivers to provide multiple redundant alerts to the selected recipients. Provide demonstration using an accepted geospatial display from Sponsor POC (SPOC) recommended system(s).

PHASE II: Construct and demonstrate the operation of a prototype system utilizing one or more handheld devices currently approved for use by USAF or SOF warfighters. Demonstrate capabilities to alert nodes to action for response as well as action to head to safety. Working with the sponsor, utilize these capabilities in one or more approved experiments or exercises.

PHASE III: Provide usability assessment of Phase II system for final user interfaces that will engage with existing receiver devices (minimum of 4--one sent from air operations center, one sent to/from SOF/embedded Joint Terminal Attack Controller or similar, and other vignette(s) determined in Phase II.

REFERENCES:
1. UFC 4-021-01, 9 Apr 2008, change 1, Jan 2010. Retrieved from http://www.wbdg.org/ccb/DOD/UFC/ufc_4_021_01.pdf.

2. AFI 10-2501_AFGM 4, 27 Jan 2012, Air Force Emergency Management Program Planning and Operations. Retrieved from http://www.af.mil/shared/media/epubs/AFI10-2501.pdf.

KEYWORDS: geographically-aware, Targeted, Secure Information Dissemination, android, handheld, alerting, warning, first responder, area notification, rapid response

AF131-041 TITLE: Low-power-cost-weight, rapidly-Installable, Medium-Range Interplane Communications Capability (LIMRICC)

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Use low-cost, low-power omni or directional wideband RF systems for interplane coordination on IP-compatible aerial networks for C2ISR wide-body mission aircraft having in-flight separation up to 100 nmi.

DESCRIPTION: Major modifications to command-control aircraft mission crew net-centric enterprise systems have taken decades to complete and hundreds of millions of dollars to implement. ESC is examining simple, low-cost, lightweight, affordable, wideband wireless systems involving minimum Group A and Group B modifications to enhance the somewhat-modernized mission systems capabilities of command-control-intelligence-surveillance-reconnaissance (C2ISR) “wide body” aircraft. Some of these mission systems, now partially-equipped for IP-like network environments, support low-level functions, such as text chat, voice over IP (VoIP), and transfer of moderately large data files/streaming data in much the same way we expect of our ground-based IP-based personal computer (PC) networks.

The goal of this topic is to provide an innovative solution for a low-cost installation, demonstration, and use of low-power, omni-directional and/or low-power, directional wideband RF systems. Support for IP or IP-like provisioning of aerial networking collaboration functions supported by Type 2 security (e.g., AES) during initial demonstration is desired. This capability may require Type 1 encryption for in-service use, which is outside of this topic’s scope. All data and systems will be unclassified for purpose of the SBIR/STTR Phase I and Phase II. The threshold range desired is 100 nmi airborne separation between aircraft. The successful bidder will also project systems changes and cost that would allow up to 150 nm aircraft separation. Since EMI determination is an MDS-specific evaluation, and will be ultimately performed by the aircraft prime, assume each of three platforms (nodes) will be within 7,000 feet of altitude and not closer than 15 nm of the other two nodes when modeling initial placement of antennae for in-cruise use. In addition, assume that two or more of these nodes could be based together and that ground test/use of the capability would be expected and demonstrated, as well.

Frequency of this interplane IP wireless capability will be somewhere within VHf to Ku Band frequencies. (VHF, UHF, L, S, C, X, Ka, or Ku band). Vendor, working with the SPOC and TPOC, will commit to demonstration in specific frequencies and waveforms authorized for military use. A multi-band system is also of interest. The minimum single point-to-point data rate required is 6 megbits per second (Mb/s) with 2 nodes on ramp, 2.5 Mb/s with two airborne nodes at a standoff distance of 40 nmi in a non-jamming flight test environment, and 250 kb/s with 2 airborne nodes at a standoff distance of 100 nmi in a non-jamming flight test environment.

PHASE I: Identify frequencies, waveform(s), antennae, likely airborne nodes, and emulation requirements. Through modeling and simulation, demonstrate the ability to meet the stated range and data rate requirements. With sponsor, identify Group A/B mods, mission applications and functions for Phase II. Identify EMI concerns and Phase II schedule. Outline interfaces to standalone mission systems.

PHASE II: Develop 4-6 complete RF transceiver units, antennae, power supplies, and power amplifiers for demonstration purposes by the midpoint of phase II. Perform bench, lab, ramp tests, and emulation demos. Comply with experiment/exercise requirements, to include flight test safety requirements. Perform flight measurements, report results and prepare for follow-on activities in next phase or commercialization phase.

PHASE III: Using CPP, project, or similar funding, provide demonstration utilizing existing or new Type 1 encryption (GFE). Provide, at least, a minimum level of interfacing to on-board mission systems; at a minimum to network-connected computers, either fixed mission systems or portable devices.

REFERENCES:
1. AIR FORCE INSTRUCTION 63-131, "MODIFICATION PROGRAM MANAGEMENT", accessible at http://www.e-publishing.af.mil/shared/media/epubs/AFI63-131.pdf.

2. Schug, Todd; Dee, Christina; Harshman, Nikki; Merrell, Ryan. "Air Force Aerial Layer Networking Transformation Initiatives". MILITARY COMMUNICATIONS CONFERENCE, 2011 - MILCOM 2011.

KEYWORDS: text chat, VoIP, data transfer, low-cost RF, interplane collaboration and coordination, application sharing among aircraft

AF131-044 TITLE: <u>Dual-band low-profile antennas for intra-flight communication and data links</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop low-profile antennas capable of Low Probability of Intercept and Low Probability of Detection (LPI/LPD), tactical data link communication between manned aircraft, unmanned aircraft, and smart weapons.

DESCRIPTION: High speed communication channels and tactical data links are becoming increasingly important for both military and commercial applications. The need for high speed inter-flight communication and data transfer is validated by the existence of the Intra-Flight Data Link (IFDL) for the F-22 and the Multifunction Advanced Data Link (MADL) for the F-35. Antennas for these two links are unique, and the two links are not interoperable. In fact, separate antennas are used on the F-22 and the F-35 for these two links.

This solicitation requests the design, construction, and delivery of low-profile apertures for simultaneous operation on multiple link bands for use in airborne environments. Possible solutions could include the use of dual-band or broadband antenna for a low profile, conformal mounting arrangement.

The target frequencies should be K band and above. The antennas should demonstrate LPI/LPD operation. The antennas should attempt to provide 1 GHz of instantaneous bandwidth. The antennas should demonstrate operation in more than one area of the band, either tunable or simultaneous operation.

PHASE I: Design a low profile, antenna array that covers at least two communication frequency bands according to requirements & quantify its expected performance. Design must: Demonstrate dual-band operation in a low profile form factor when mounted on a large conductive surface. Provide a trade-off analysis of critical performance characteristics (gain, field-of-view (FOV) bandwidth, impedance, etc.).

PHASE II: Construct, demonstrate, test, and deliver dual-band low profile antenna arrays based on the designs proposed in Phase I. The prototype must include operation at the two communication and/or data link frequency bands referenced. The prototype's salient performance parameters (e.g. gain, FOV, bandwidth, input impedance, etc.) must be measured, compared with model predictions, and reported.

PHASE III: Develop conformal dual-band antenna arrays for airborne use. The antenna arrays must be able to demonstrate operation in at least the two communication and/or data link frequency bands referenced.

REFERENCES:
1. W. Stutzman and G.Thiele, Antenna Theory and Design, J. Wiley & Sons, 1981.

2 N. Amitay, V. Galindo, and C. Wu, Theory and Analysis of Phased Array Antennas, J. Wiley & Sons, 1972.

KEYWORDS: communications, data links, conformal, airborne, antennas, arrays

AF131-045 TITLE: <u>Ground Based Sensor for measurement of V and W band satellite link propagation channel</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a ground based sensor to measure the propagation characteristics along the earth-space path for the V and W bands of 71-76 GHZ and 81-86 GHz.

DESCRIPTION: Development of new satellite communications capabilities in the allocated V and W frequency bands of 71-76 GHz and 81-86 GHz require measurement of the atmospheric attenuation characteristics at these frequencies. This includes measurement of the fade dynamics as well as the long term attenuation statistics (exceedance probabilities). Since the key design parameter for satellite communication systems is link margin, measurements of multi-year attenuation statistics for a variety of global locations and climates are a necessity. Predictive attenuation models derived from beacon measurements have been developed for frequencies at Ka-band and below, however none exist for the V and W bands. Extrapolation of these Ka-band models to the V and W band frequencies is uncertain. There is a dearth of relevant data at millimeter wave frequencies available to test or develop predictive models. The usual approach to collecting attenuation statistics utilizes geo-stationary beacon(s) and multiple receiver locations. Alternately, a stand-alone ground based sensor that is capable of determining the attenuation characteristics without the need for a beacon is attractive. Such a ground based sensor capability can provide the much needed data at a much lower cost and greater flexibility in site location than approaches requiring a geo-stationary beacon.

Performance goals call for a capability to determine the attenuation over a dynamic range greater than 20 dB with an uncertainty of less than 10%. The sensor should be able to determine attenuation under most atmospheric and weather conditions including light and moderate rainfall. It should be designed to operate over a broad range of elevation angles; from 20° to 90°. The sensor should be designed as a capable of operating continuously with minimal direct operator control.

The proposed effort will develop an architecture and a sensing strategy, including the desired measurement suite and retrieval algorithm(s). It is expected that the sensing strategy will require integration of multiple measurement capabilities including meteorological data.

Passive radiometry offers one possibility to collect the needed attenuation statistics. Radiometers have been widely used for passive (remote) sensing and retrieval of various atmospheric properties. Radiometers have been used for accurate attenuation measurements in an absorptive atmosphere, but with limited dynamic range. The brightness temperature measured by a radiometer is related to the absorption and scattering of the atmosphere. Calculating attenuation from brightness temperature measurements (retrieval) is the central issue for such an approach to ground based sensing.

These sensors will provide key data needed to define satellite communication system architectures. Multiple sensors will be required to collect the attenuation characteristics at a variety of geographic locations. Additionally, this type of sensor may be used in an operational capacity for short term predictive forecasting and dynamic adaptive fade mitigation, and may be generalized for use with other frequency bands.

PHASE I: Conduct analysis to determine the sensing strategy and expected performance of a ground based system to measure atmospheric attenuation for a satellite communication system in the V and W bands. Specify the hardware to provide measured input data for the attenuation retrieval algorithms. Indentify critical engineering challenges to building the ground based sensor.

PHASE II: Build a prototype ground station that includes the necessary suite of atmospheric measurement capabilities. The effort should demonstrate the expected system performance through analysis and simulation.

PHASE III: Produce a multitude of ground stations based on the phase II prototype in order to perform multi-year attenuation measurements at a variety of global locations. The commercial satellite industry can use these technologies.

REFERENCES:
1. G. Brussaard and P.A. Watson, "Atmospheric modeling and millimeter wave propagation", Chapman & Hall, 1995.

2. E. Westwater, S. Crewell, C. Matzler, "Surface-based microwave and millimeter wave radiometric remote sensing of the troposphere: a tutorial", IEEE Geoscience and Remote Sensing Society Newsletter, March 2005.

3. F. Ulaby, R. Moore, and A. Fung, "Microwave Remote Sensing", Addison-Wesley, 1981.

KEYWORDS: Radiometer, radiometry, radiowave-propagation, satellite communications, millimeter wave, atmospheric absorption, atmospheric attenuation, V-band, W-band

AF131-046 TITLE: <u>V/W Band Airborne Receive Antenna</u>

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a transmit (81 to 86 GHz) and receive (71 – 76 GHz) airborne antenna.

DESCRIPTION: Demand for military satellite communication capability continues to increase. In response, the Air Force is exploring the use of V-band (71-76 GHz) for a future high-capacity satellite downlink capability and W-band (81-96 GHz) for an uplink capability. The key risk that will be addressed by this research topic is the airborne antenna. As a pathfinder for the actual operational system, a demonstratable antenna capability will be prototyped. This unit will be airborne-qualifiable and built with best practices for the airborne application. It will include a V/W rotary joint capability.

Size, weight, and power are key constraints for airborne components. For the prototype capability, the overall cost of a future operational antenna (based on the prototype design) will be considered.The polarization of the antenna will be right hand circular polarization (RHCP) on transmit (81 to 86 GHz) and left hand circular polarization (LHCP) on receive (71 to 76 GHz). The anticipated gain of a design will be greater than 52 dBi. The total efficiency of the antenna will be greater than 60%, the sidelobe suppression level will be -14 dBic or lower, and the cross polarization isolation will be greater than 20 dB.

For a successful airborne qualifiable design, the airborne environment, common RTCA/DO-160 environmental conditions and test procedures shall be used during the course of the design. Some environmental constraints include an operating temperature range that will be -20 to 55 degrees Celsius, along with an intended operating altitude from sea level to 27,000 ft. The non-operating altitude will be sea level to 65,000 ft.

PHASE I: Phase I will establish a thorough antenna design through modeling and simulation. The final report will outline a path to build an airborne-qualifiable antenna.

PHASE II: Phase II will take the antenna design from Phase 1 and build a prototype antenna that consists of all or part of the final complete design. This prototype will verify the ability to manufacture the entire antenna for the intended purpose. This will include a rotary joint capability.

PHASE III: Airborne MILSATCOM systems would benefit from high capacity satellite uplink / downlink capability at V-band and W-band. The commercial market is also interested in extending satellite service into higher frequency bands.

REFERENCES:

1. Pratt, T., Bostian, C., Allnutt, J., Satellite Communications, 2nd edition, John Wiley & Sons, 2003.

2. De Fina, S., Ruggieri, M., Bosisio, A.V., "Exploitation of the W-band for high capacity satellite communications," IEEE Transactions on Aerospace and Electronic Systems, Vol. 39, Issue 1, pp. 82 – 93, 2003.

3. Perrotta, G., Jebril, A., Ruggieri, M., "Early Experiments with W-band Satellite Links," 2006 IEEE Aerospace Conference, pp. 11, 2006.


KEYWORDS: Space Communication, W-band, satellite uplink antenna

AF131-047 TITLE: Secure Cloud Computing Environment for Infrared (IR) Data

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a cloud computing architecture that can transport infrared data securely and in compliance with DoD standards [1].

DESCRIPTION: The Tech need is for ISR data gathered by space-based IR sensors to be made available to the warfighter using the Secure Cloud. While Infrared (IR) space surveillance data is typically massive, it must reach Warfighters in the field via a very narrow (56k) communication channel. Two known ways to reduce the data volume are implementing IR data compression and requiring that the Warfighter select a more focused area of interest. The first of these, compression of the IR data, could be implemented on a server at the data downlink side. However, such a point to point solution would decrease the system's resiliency against attack. A cloud (community) computing [2] approach could solve the data compression challenge while simultaneously increasing the system's resiliency.

Furthermore, applying this "cloud computing concept" to the storage, processing, and management of IR data could facilitate increased future sharing of IR data across the larger user community, opening the door to more innovative user-developed applications, processes, and capabilities aimed at satisfying a wide variety of user need and requirements. Each eligible user could be given their own customizable web environment and allowed to develop custom applications and personalize their interface to meet their unique requirements. For instance, a Google Maps-like user interface familiar to any Internet user could be adapted for the presentation of Geospatial IR data through the use of a Google Maps Application Programming Interface (API) [4], and the benefits of such a capability could be easily shared with others throughout the larger community. The moderators of the "cloud centric" community could then adopt the best of these user developed applications and tools, enhance them by incorporating additional capabilities, and deploy them as standards and templates across the enterprise.0 This solicitation seeks the development of an innovative cloud computing architecture for IR data that is secure [3] according to DoD standards [1].

The architecture must have the following characteristics:
1. IR data specific compression

2. Feedback loop from Warfighter for selection of data
3. Support current fielded Warfighter equipment
4. 95% availability
5. No disruption in service when switching service provider. Temporally downgraded performance is acceptable

Example IR target data can be supplied by SMC/ISR.
Note: No foreign nationals can work on this project.

PHASE I: The Phase I work will develop the concepts for the Cloud computing environment for processing of space-based IR data and will examine feasibility of the concepts.

PHASE II: Phase II should include fabrication of a representative prototype to demonstrate the performance, security, feasibility, availability analysis, and non disruption feasibility of the concept.

PHASE III: Military application: Secure cloud computing environment for use by any DoD organization; can be for a wide variety of data types. Commercial application: Secure cloud computing environment for commercial application to organizations such as communications or financial firms.

REFERENCES:
1. http://diacap.org/.

2. NIST Special Publication 800-146, Cloud Computing Synopsis and Recommendations, May 2011, http://csrc.nist.gov/publications/drafts/800-146/Draft-NIST-SP800-146.pdf.

3. Cloud Security Alliance publication, Security Guidance for Critical Areas of Focus in Cloud Computing, November 14, 2011, https://cloudsecurityalliance.org/guidance/csaguide.v 3.0.pdf.

4. http://code.google.com/apis/maps/index.html.

KEYWORDS: Cloud computing, data security, infrared data

AF131-048 TITLE: Channel and Interference adaptive SATCOM Digital beam-former

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop an adaptive digital beamformer that can adapt to the RF channel and interference conditions for optimal throughput and/or reception quality.

DESCRIPTION: A beam forming system uses an array of antenna feeds to form a desired composite antenna pattern. This is accomplished by weighting (amplitude and phase shifting) each individual feed and then summing the weighted feeds. An algorithm is used to derive an optimal set of weights to form a composite pattern which may, for example, electronically "steer" to a desired source signal, or null an undesired interferer.

To date, most satellite uplink beamformers apply their weights to the RF signals received by the feeds (usually after a low-noise amplification stage) [1]. Following weight combining, downconversion and filtering are performed to 1) isolate a particular frequency band containing the signal of interest, and 2) reduce the bandwidth of the signal in preparation for analog-to-digital conversion.

A drawback of this approach is that the weights are frequency-independent and therefore, very little opportunity exists for shaping the composite antenna pattern over frequency. For example, if a user is located at angle ? and frequency f1 while an undesired interference exists at ? and f2 then we would like an antenna pattern with a main lobe at (?,f1) and a null at (?,f2). However, with frequency-independent weights, the pattern is necessarily also frequency independent. Some systems, such as AEHF, overcome this limitation by "sharing" the beam. In such a system, a TDMA scheme is employed in which, for a given time slot, the weights are optimized for one user. The composite beam is steered to the user and bandpass filters isolate the user from interference. On the next time slot, the beam steers to the next user. However, in such a system, the achievable throughput is degraded by the amount of beam sharing.

If the beam forming could be done digitally, then a filter-and-sum [1] approach could be followed in which the weights are replaced by linear filters. This would allow for composite patterns that vary with both spatial direction and frequency. Such patterns could enable all users to communicate with the satellite simultaneously so long as they maintain separation in space or frequency. Such implementations were not feasible in the past as they require wideband ADC's which can digitize the entire satellite band. This type of digital beamformer could achieve a significant improvement in throughput versus a beam shared system. In fact, the throughput could potentially increase by a factor of M where M is the number of users sharing the beam.

The optimal weights for a given user/interference scenario must be derived. Since the digital implementation gives the processor access to all feeds and all frequencies, an adaptive algorithm is a likely method for deriving optimal weights. The large amount of information available to the processor opens up many possibilities for weight update algorithms.

This SBIR is seeking a SATCOM digital beamformer technology and implementation that is adaptive to the channel and interferences. The proposed beamformer should demonstrate adaptation of the beamformer weights to optimize for various impairments experienced in the satellite channel such as interference, jammers, non-ideal antenna frequency dependent characteristics, and fading. Moreover, the implementation should demonstrate new capabilities in enhancing throughput for example by simultaneously receiving multiple channels with improved reception quality.

The proposed system should be agnostic to the RF frequency, bandwidth, number of digital bits, and modulation types. It should be able to operate in the same vibration, temp, and radiation environment as the existing WGS and AEHF SATCOM terminals.

The simulation model should include a high-fidelity SATCOM channel model that accounts for atmospheric condition, and various interference and jamming conditions. The simulation performance should quantify the beamformer performance that is adaptive to the changing atmospheric and interference conditions. The simulation model should be bit-exact and is ready for the FPGA implementation.

This research on the improved beam forming technology will ultimately find utilization within the commercial satellite communication systems to provide enhanced reception and reliability of voice, video, and data transmissions via commercial satellites.

PHASE I: Investigate architecture and algorithms to determine the feasibility of implementing an adaptive beamformer for satellite communications via mathematical analysis and model and simulation. Investigate the feasibility of the proposed beamformer to operate in the comm-on-the-move environments.

PHASE II: Develop and demonstrate a prototype adaptive beamformer for satellite communications. The demonstration system should integrate the adaptive beamformer hardware with the COTS components to form a complete SATCOM terminal. For the demonstration purpose, the Ka-band WGS (30-31 GHz uplink and 20.2-21.2 Ghz downlink), and the SHF-band AEHF (44GHz uplink and 20GHz downlink) should be used as examples.

PHASE III: Integrate the prototype unit to demonstrate its capability in beamforming for various military systems such as WGS and AEHF. Improved beam forming technology will ultimately find utilization within commercial satellite communication systems.

REFERENCES:

1. L. Wang and D. Ferguson, WGS Air-Interface for AISR Missions, IEEE 2007 MILCOM.

2. D. H. Johnson and D. E. Dudgeon, Array Signal Processing: Concepts and Techniques, Prentice-Hall, Upper Saddle River, NJ, 1993.

3. http://docdigger.com/docs/digital_beamforming_(dbf).html-article on Digital beam forming.

KEYWORDS: Satellite communications, RF, digital beamforming, communications on the move, interference, jamming

AF131-049 TITLE: New wavefroms for anti-jam satellite communications

TECHNOLOGY AREAS: Sensors, Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a chaotic spread spectrum waveform suitable for use in future military satellite communications applications providing featureless transmission characteristics as well as the capability to overcome jamming or interference.

DESCRIPTION: Transmission Security (TRANSEC) involves insuring that there is no loss in satellite communications signals through either unintentional interference in a crowded space environment or intentional jamming. In addition, with enhanced signal detection and monitoring capabilities of potential adversaries, there is a need to effectively mask communications signals between satellites and ground assets. Recent research suggests that a flexible chaotic communications waveform family could provide high information density, with improved waveform protections for anti-jam and low probability of intercept/detection/exploitation. The purpose of this topic is to develop and demonstrate a bandwidth efficient, cost effective, chaotic spread spectrum waveform with excellent AJ (anti-jam) capability suitable for use in future military satellite communications applications while minimizing adjacent channel interference by leveraging research such as chaotic constant amplitude zero autocorrelation (CAZAC), variable high peak-to-average power ratio (PAPR) chaotic spread spectrum, chaotic Quadrature Amplitude Modulation (QAM) spread spectrum, chaotic multiple access spread spectrum, self-encrypted chaotic multiple access communications, and channelized chaotic communications. The program may also address robust transmitter/receiver synchronization algorithms that mitigate noise and communications channel distortions to improve Bit Error Rate (BER). Recent advances in processor speed should provide a further enhancement by enabling these waveforms to hop faster over the spectrum. To date, the vast majority of chaotic spread spectrum research has been only theoretical, and as such, the state-of-the-art in this area has yet to be defined. The goal of this effort will be to evaluate and transition one or more of the most promising and practical theoretical designs into a workable hardware and/or software design (Phase I) that can be demonstrated in material form (Phase II). A primary focus of the research will be to seek reductions in the size, weight and power (SWAP) over legacy spread spectrum implementations for deployment of a highly-effective Anti-Jam (AJ) and Low Probability of Intercept / Low Probability of Detection / Low Probability of Exploitation (LPI/LPD/LPE) capability, low-cost tactical user terminal for use in hostile environments. Specific design goals include minimization of bit error rate (BER), spectral side-lobes, faster spectral hopping and, where appropriate, the capability of being partitioned in the current generation of radiation hardened components, particularly FPGA's (Field Programmable Gate Arrays). The Phase I design and Phase II prototype should address a minimum data rate of 1 Mb/s at a bit error rate of less than 1x10-6 over a minimum spreading bandwidth of 10 MHz.

PHASE I: Design an optimum chaotic spread spectrum waveform which addresses the above requirements, and which has the potential to be practically and cost-effectively implemented via a hardware and/or software approach.

PHASE II: Develop and implement the Phase I hardware and/or software design into a functional prototype that can be used to demonstrate the waveform performance in either a simulated or actual operational environment. Develop quantitative measures and characterize for BER, LPI/LPD/LPE/AJ, link capacity, frequency hop rate and SWAP.

PHASE III: Military applications for this technology include warfighter satellite communications and AISR. Commercial applications for this technology include internet routing.

REFERENCES:
1. Cryptographic CDMA code hopping (CH-CDMA) for signal security and anti-jamming, Frank Hermanns, Deutsches Zentrum fur Luft-und Raumfahrt (DLR), German Aerospace Center, Institute for Communications and Navigation, D-82234 Weßling, Germany, and University of Armed Forces, Neubiberg B. Munchen, Institute of Information Technology.

2. Efficient and flexible chaotic communication wavefrom family,A.J. Michaels, IEEE Explore Digital Library, Military Communications Conference, 2010.

3. Efficient and Flexible Chaotic Communication Waveform Family, Alan J. Michaels, Ph.D., David B. Chester, Ph.D., Harris Corp., GCSD.

KEYWORDS: Transmission Security, Anti-Jamming Comm, Chaotic spread spectrum, waveform with AJ, chaotic constant amplitude zero auto correlation (CZAC), variable high peak-to-average-power ratio (PAPR)

AF131-050 TITLE: SATCOM Wideband digital channel analyzer

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a low cost silicon-based wideband digital channelizer for the military Ka-band WGS terminal that down-converts, digitizes, and channelizes L-band (950–2150 MHz) intermediate frequency (IF) into multiple channels of baseband signal.

DESCRIPTION: Current military Ka-band WGS SATCOM terminal employs multiple digital receivers to process signal in different channels. For example, four digital receivers, each with a 125 MHz bandwidth can be employed to process signal in a 500 MHz bandwidth. The multiple number of digital receivers increases Size Weight and Power (SWaP) and cost. Recent research [2][3][4] focuses on the superconductor based mixed signal data converter to achieve direct digitization starting from the Radio Frequency (RF) signal. However, because of the cooling requirements, such systems are expensive and bulky. There are also other all-digital approaches [5] available, by focusing primarily on the digital processing; however, they do not offer an integrated, low-cost solution.

This SBIR is seeking an IF L-band (950-2150MHz) digital channelizer that provides cost and SWaP advantages over the above implementations by leveraging low-cost silicon technology such as CMOS. The key technology being sought in this SBIR is the IF L-band digital channelizer to down-convert the entire IF L-band signal, digitize the signal in a 500 MHz bandwidth, and produce multiple signal streams in different channels. The L-band digital channelizer combines the down-conversion, digitization, and channelization functions together in a single module. The number of channels should be configurable (1, 2, 4, 8, 16, 32, 64) based on individual channel's bandwidth, with a total bandwidth of 500 MHz.

The proposed wideband digital channelizer should be a single compact unit using low cost silicon technology. The proposal should apply a holistic approach that utilizes signal processing techniques for the effective filtering and the digitization resolution improvement (number of bits) with the sample rate of 1 Giga sample per second (Gsps), which corresponds to a 500 MHz bandwidth. Such holistic approach may include sophisticated digital calibration to correct for circuit impairments such as device mismatches and image imbalance that currently limits the filtering performance and the wideband analog-to-digital conversion resolution to a single digit in low-cost silicon technology. The holistic approach should apply system optimization to the channelizer design that utilizes signal processing as well as circuit design considerations to increase the wideband digitizer resolution to >12b using the low-cost silicon technology. The power consumption of the proposed channelizer should be less than 1W, and should operate in the 950-2150 MHz L-band.

Impacts to the high bandwidth efficiency modulation are beyond the scope of this SBIR. The wideband digital channelizer shall be able to operate in the same vibration, temp, and radiation environment as the existing Ka-band WGS terminals.

The theoretical analysis should takes into account of the atmospheric condition, the imperfectness in the RF front end, IF, and baseband implementations.

The model and simulation should be at the bit-level and should produce precise performance estimation. The simulation source code should be readily applicable to the FPGA implementation.

PHASE I: Investigate circuit, architecture, and processing algorithms to determine the feasibility of producing a L-band IF wideband digital channelizer with greater than 12b resolution at 1GSps sampling rate, and consuming less than 1W of power. The investigation should include the theoretical analysis, circuit and architectrue design, and model and simulation.

PHASE II: Develop and demonstrate a prototype wideband digital channelizer hardware. The demonstrated channelizer should take the L-band IF output from an existing Ka-band WGS terminal, and produces multiple channels (1, 2, 4, 8, 16, 32, 64) of baseband digital signals. The baseband digital signals should then input into COTS demodulator device for baseband processing. QPSK modulation should be used for demonstration purpose.

PHASE III: The digital channelizer can be integrated into Ka-band WGS terminal to process L-band signal into multiple channels. This should reduce the SWaP of the SATCOM terminal. Research can be used within commercial satellite communication systems to enable simultaneous tuning of multiple channels.

REFERENCES:
1. L. Wang and D. Ferguson, WGS Air-Interface for AISR Missions, IEEE 2007 MILCOM.

2. D. Gupta, et. al., Digital Channelizing Radio Frequency Receiver, IEEE Transaction on Applied Superconductivity, vol. 17, No. 2, June 2007.

3. S. Sarwana, et. al., Multi-band digital-RF receiver, IEEE Transaction on Applied Superconductivity, Vol. 21, No 3, Jan. 2011.

4. W. Littlefield, A reconfigurable, digital Multi-band SATCOM terminal: Closer than you think, White paper from Hypres.

5. H. Beljour, et. al., Proof of concept effort for demonstrating an all-digital satellite communications earth terminal, IEEE 2010 MILCOM.

KEYWORDS: satellite communications, wideband, IF, digital receiver, down-converter

AF131-051 TITLE: <u>Conflicting, Suspicious, and Inconsistent Information Detection (CSI-Info)</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Investigate and develop techniques to detect and resolve conflicting, inconsistent, suspicious, and deceptive content (i.e., misinformation) present within multiple sources of information.

DESCRIPTION: We face an adversary that is adept at using ubiquitous forms of communications, transactions and movements to organize, and execute operations. These activities generate diverse types of information which can include a considerable amount of conflicting, incomplete, incorrect or even deceptive content. Some of this misinformation may be due in part to errors in research, reporting, translation, or transmission. In other cases, incorrectness is due to deliberate attempts to deceive, based on motives ranging from personal to criminal. Better techniques are needed to help reduce the uncertainty in analysis associated with this misinformation. There has been a great deal of progress in the past decade developing new techniques and representations for reasoning under uncertainly. Many approaches have also been explored for modeling suspicious, illegitimate and/or deceptive behavior, including agent-based approaches, graphical models, guilt-by-association, and expert systems. We are seeking methods that leverage semantic and syntactic techniques, pedigree and lineage (provenance) and provide salience (weights) to the association assertions made within and across sources. Bayesian techniques and graphical models have been widely accepted, and there is a great deal recent progress on probabilistic logic, using approaches such as Markov Logic Networks. Similarity scoring methods that can incorporate new evidence with uncertainty and credibility are also needed.

Of key interest to this topic will be an ability to discriminate between legitimate and illegitimate information. This can be very difficult when individuals and groups use deception to disguise their behavior. For example, an adversary might create numerous false identities or relationships in the virtual community to mask their true connections or project a false perception enabling them to operate clandestinely. Tactics such as the use of pseudonyms, varied travel patterns, frequent location changes, and indirect methods of communications can make it difficult or impossible for authorities to detect their presence and monitor their activities. Unfortunately, there are few, if any, techniques that the research community has subjected to replicable experiments to address this problem. Regardless of the approach or application, there are common issues. For instance, one common problem is that the data is typically unbalanced and noisy.

For the purpose of this topic, information is limited to semi-structured and structured sources such as web pages or stored in databases. Natural Language Processing (NLP) technology dealing with unstructured sources such as open source text should not be considered. It is assumed that entities and relationships present in natural language will have already been extracted using NLP methods. Domain expert involvement and feedback will be critical for validation and improvement.

The goal of this SBIR topic is an automated (or semi automated) capability that can examine information associated with entities, events and the relationships that exist between them, identify misinformation, and suggest possible resolutions if they exist. This capability will help reduce uncertainty and lead to more accurate analysis, better situation awareness and enhanced decision making.

PHASE I: Research and develop an innovative approach to meet the SBIR Topic requirements, and assess its feasibility. Develop the initial design for a prototype and demonstrate its application. A proof of concept is required to demonstrate feasibility of approach.

PHASE II: Develop the required technologies and prototype, per the Phase I design. Develop and demonstrate prototype tools and techniques for monitoring activities and trends of entities in domains of interest for Air Force users using real-world data. A working prototype is required.

PHASE III: Disciplines such as Human Intelligence (HUMINT), and Document Exploitation (DOCEX) lack well established methods for detecting and countering misinformation. Business and law enforcement applications could include money laundering, Arms Trafficking, Fraud, cybercrime and identity theft.

REFERENCES:
1. Montagu, E. The Man Who Never Was, J. B. Lippincott Company, Philadelphia, PA (1954).

2. W. Winkler. Overview of record linkage and current research directions. Technical report, Statistical Research Division, U. S. Bureau of the Census, 2006.

3. W. W. Cohen, P. Ravikumar, and S. E. Fienberg, “A comparison of string distance metrics for name-matching tasks”, In Proc. of IIWEB, pages 73-78, 2003.

4. X. L. Dong, Data Fusion – Resolving Data Conflicts in Integration, www2.research.att.com/~lunadong/talks/dataFusion_ndbc.pptx.

KEYWORDS: Entity resolution, Conflict resolution, Data Association, Deception Detection, Mis-information, Intelligence

AF131-052 TITLE: Cross Domain Dissemination

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop and automated means to provide intelligence data with assured and appropriate classification and releasability markings through metadata tagging. This will be used to enhance information sharing between multiple, independent security domains.

DESCRIPTION: Automated cross-domain data dissemination is limited by the lack of consistent classification and releasability markings (imagery, signal intelligence (SIGINT), ground moving target indicator (GMTI), etc.) on metadata with integrity seals from sensors. Most Intelligence Surveillance and Reconnaissance (ISR) sensor data have fields which are inconsistently populated hampering sharing and discovery. This can extend the timeline for conducting analysis by requiring the analyst to manually search multiple sources for significant data, evaluate the various information sources to properly assess the situation, and then document and disseminate the findings internally and externally. The ability to generate a capability to mark data based upon mission profile and releasability for all pertinent sensors and generate a modifiable default value that would be used when unmarked data is received is required. Investigate ways through probabilistic methods and/or cloud-based distributed environments to automatically mark the unmarked data based on historical data with high accuracy. Having this capability would enable near real-time and real-time exchange, dissemination, search, access, display and association of disparate information across multiple communities of interest both internal and external to a given analytical organization. Measuring percentage of missing metadata from the document corpus prior to the systems use and after should be documented and measured. Developed prototype solution must leverage metadata tagging standards & tools from within Department of Defense (DoD) and Intelligence Community (IC) where appropriate.

PHASE I: Create a prototype to evaluate completeness & correctness of metadata. Automatically add appropriate metadata to close any gaps. Data formats used must be representative of those used in ISR community (provided by Government). Use prototype to check existing data repositories for mis-tagged data. Identify cases where non-standard metadata is used.

PHASE II: Test developed tool within sample ISR data repository and identify insufficiently tagged data that would inhibit secure exchange across disparate communities of Interest. Report results of investigation and identify plan for automatic data tagging enhancements for the tool. Report any newly identified cases of proprietary and non-standard data. Enhance prototype to automatically, consistently and appropriately mark existing data that is insufficiently or inappropriately tagged.

PHASE III: Develop documentation and training program for this tool, sufficiently demonstrate this tool within a realistic ISR exercise and deploy it within ISR community.

REFERENCES:
1. Understanding metadata, NISO Press; www.niso.org/standards/resources/UnderstandingMetadata.pdf

2. DoD Data Services Environment; https://metadata.ces.mil

3. Geospatial Metadata; www.fgdc.gov/metadata

4. GOV standards for geospatial metadata; http://www.fgdc.gov/metadata/geospatial-metadata-standards/

KEYWORDS: metadata tagging of sensor data, automatic sensor tagging, metadata validation, inadequately tagged intelligence data

AF131-054 TITLE: Presentation and Management of Blue Force Capabilities

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Define, develop, and demonstrate innovative approaches to accurately present and represent globally-distributed blue force readiness and capability (comprising air, space, and cyberspace assets) in a timely manner.

DESCRIPTION: Today's blue forces are globally distributed and supporting missions worldwide. Traditional Command and Control (C2) systems deal with blue forces in relation to their geographically-defined location and domain-specific missions. The current technical approaches do not enable a C2 capability to efficiently and effectively represent and manage blue forces in a dynamically changing environment across the air, space, and cyberspace domains.

Blue forces are the resources that are utilized for the mission, which could include hardware entities such as planes or hardware assets on the network like routers and switches, software systems for C2, sensors, and the people. Blue forces could be considered any part of our ability to conduct operations, be it logical or physical.

A comprehensive visualization of blue force status or readiness and capability in near real-time across the air, space, and cyberspace domains is the desired capability of this effort. Solutions should be able to accurately represent and provide shared understanding of air, space and cyberspace blue force capabilities, or a mixture of these forces, in a timely manner. Issues with this include incomplete data, uncertainty, conflicting data, capturing and maintaining real-time state, understanding timeliness, data fusion and more. By accurately representing blue forces throughout all domains and between mission partners the means to achieve integrated economy of force is feasible. Solutions could also consider creation of effects by novel mixing and matching of capabilities in and across the air, space, and cyberspace domains to achieve desired outcomes. Key will be the ability to understand the D5 effects (e.g. destroy, deny, disrupt, degrade, and deceive) and/or non-military effects such as providing humanitarian relief (situation awareness, communications, shelter, etc.) that can be delivered and how one can aggregate data to produce the desired effects for a package of assets. Solutions should also provide innovative technologies to display blue force status for forces in all domains (air, space, cyber) in a visualization to allow users to understand their blue force status and capabilities to enhance planning.

A solution of this capability will allow military commanders and operators to know what resources are available to them, where they are, and how they can best use them.

PHASE I: Define relevant use cases to assist analysis and identification of potential solutions. Perform trade analysis to select and recommend a solution for representing air, space, and cyberspace or a combination of forces to address the capability desired. Develop a design concept and/or prototype demonstration of selected technology solutions.

PHASE II: Develop, demonstrate, and validate the prototype in a relevant scenario clearly demonstrating ability to meet the desired capabilities in a Service Oriented Architecture (SOA).

PHASE III: Military command centers will benefit from knowing what resources are available to them, where they are, and what they can do. Commercial benefit comes from understanding one's resources to meet market demands.

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1. AF/ST-TR-10-01-PR, Technology Horizons, Volume 1, 15 May 2010.

2. Command and Control Rapid Prototyping Continuum (C2RPC) The Framework for Achieving a New C2 Strategy : http://www.dtic.mil/dtic/tr/fulltext/u2/a546926.pdf.

3. Semantic Web: www.w3.org › Standards.

4. JP 5-0 Joint Operation Planning: www.dtic.mil/doctrine/new_pubs/jp5_0.pdf.

KEYWORDS: command and control, decision making, planning, synchronized operations, scheduling, ontology, resource description framework, information management, force presentation, force capability

AF131-055 TITLE: End-to-End Network Trust

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Provide end-to-end, adaptive trust in a complex network infrastructure. Each component in the infrastructure must be able to establish trust, verify the trust of other components in the infrastructure, and provide trusted communications.

DESCRIPTION: End-to-end trust is an emerging field in cyber security and should be an essential part of any mission-critical operation or secure electronic communication. Being able to verify the trust among, and the communications between, critical components is paramount to preventing compromise of discrete operations. It is not feasible to assume that the devices across a network can all be trusted. This effort requires a solution that provides end-to-end trust on a network, even in the presence of compromised or malicious components which may have or have recently had a trustworthy connection. A network infrastructure can be comprised of many components, such as servers, routers, desktops, mobile devices, and smart phones. Transmitting information from one component to another is complex and riddled with insecurities. For example, an adversary could potentially compromise a router between two components and perform a man-in-the-middle attack on their communications. The goal of this effort is to provide methods to verify the integrity of the components of a network infrastructure, as well as to provide a means to securely collaborate between components, even in the presence of malware. That is, the goal of this effort is not to prevent or detect the presence of an attack or malware, but instead will focus on how to measure, and verify that software on a component hasn't been tampered with by an attack (i.e. can the software be trusted). In addition, techniques must be provided to periodically maintain and reestablish the trust of a component. A technique must be provided for a component to determine if it has experienced a loss of trust. Upon a component losing trust (e.g. possibly from a cyber-attack), this component should no longer be able to communicate with its previously trusted interconnected components. A method to communicate the trustworthiness between two components and establish a trusted connection shall be developed & utilized. This communications method will also support notification of detection of untrustworthy components as appropriate. The end-to-end security established should be able to survive on a network that is compromised by an adversary with intimate knowledge of the solution provided. The methods and protocols must be resilient to an attack even if the entire technique is known. Even after a trusted path between multiple components has been established, it is necessary to maintain this path to ensure that trust is maintained. This effort shall identify a means to preserve trust between components in order to maintain secure operations. Verified components shall be assigned an associated level of trust. This level of trust will be used to determine security criteria for the type of data that can be transmitted across these components. This capability must preserve network bandwidth as much as possible and minimize or preferably eliminate customization or replacement of components. Note that components can be physical and/or virtual and the proposed response will need to be able to address both.

PHASE I: Identify all of the resources in the system that must be measured, determine a method for secure communications, and demonstrate end-to-end trust providing adaptation to one or more trusted components being subverted. Perform/report an analysis of alternatives and demonstrate techniques to verify/maintain the trust of each type of critical component in the overall system.

PHASE II: Extend prototype for complex environment with multiple end-to-end processes with adversaries present who are aware of the approach used. Provide the ability to measure & determine the trustworthiness of software both at boot time and during run-time; include secure communications between all nodes on the network; include heterogeneous nodes & include the ability to react to compromised nodes by showing nodes renegotiating trust as processes and components are disrupted or subverted.

PHASE III: Military Application: Utilize developed technologies to automate process of assuring trust across large mission-critical network. Commercial Application: benefits industries where trust and privacy are essential to business (incl. banking, medical, eCommerce, DHS, & commercial businesses.

REFERENCES:
1. “End to End Trust: Creating a Safer, More Trusted Internet”. www.microsoft.com/mscorp/twc/endtoendtrust/.

2. Defrawy, Karim, et al. “SMART: Secure and Minimal Architecture for (Establishing a Dynamic) Root of Trust”. Feb 8, 2012, NDSS 2012.

3. NIST Special Publication 800-53, "Recommended Security Controls for Federal Information Systems and Organizations"
http://csrc.nist.gov/publications/nistpubs/800-53-Rev3/sp800-53-rev3-final_updated-errata_05-01-2010.pdf

KEYWORDS: End-to-End Trust, Secure Communications, Information Assurance, Interoperability, Information Exchange, Security Guards

AF131-057 TITLE: Automated Analog Electronics Design Tools for Obsolete Parts

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop design tools to facilitate fabrication of obsolete, radiation-hardened, precision analog components. Design tools must address the development methodology with Electronic Design Automation data and industry standards.

DESCRIPTION: Current systems require routine maintenance of the electronics components. Due to the long lifetime of these systems many of the components for these systems will likely become obsolete. The community has addressed many of the digital component issues but there is a need to address the analog portion of the system components.

The advances in the commercial electronics industry present challenges to the acquisition of replacement, radiation-hardened, precision analog electronics. The expense of manufacturing microelectronics components at today’s technology nodes makes it infeasible for industry to produce components for the limited strategic weapons market. A particular concern is that changes to the fab process during the life of an originally rad-hard component may reduce the hardness below acceptable levels. To take advantage of the current defense microelectronics manufacturing capability, a solution is sought to develop design tools to facilitate the re-design of legacy precision analog microelectronics components that are hardened against ionizing radiation with emphasis on dose rate and neutron fluence protection. These tools would be used to translate the component specifications into a manufactured or fabricated design using one or more fabrication facilities. The EDA tool should provide Graphical, table and/or listing feedback to the user indicating design specification achievement and/or comparison.

Development activities shall include a study of current design tools, industry standard formats, tool features, Graphical User Interfaces, market adoption, platforms hosted, product support, data interfaces etc. Tool features such as graphic drawing, parameter/cell search utilities library viewer, command/log file and GDSII viewer available with user friendliness considered.

PHASE I: Develop solution and methodology, to enable precision analog components from one fabrication process to be re-defined for fabrication on target process given a functional description of the original component and specification of the radiation environment. Coordinate with target manufacturer ensuring proper application of design rule checks, proper formats for passing design files, etc.

PHASE II: Implement the design solution and fabricate an analog system using the design tool(s) developed in Phase I. The tool(s) will provide an operational demonstration in accordance with Air Force/contractor agreed specifications. The system will consist of functional, radiation-hardened test structures at a minimum with the goal of achieving a fully functional, radiation-hardened, analog component. The product transition strategy will be identified. IC industry data standards can be utilized.

PHASE III: Design tools for analog components for electronics systems are of interest to strategic and non-defense government and commercial space sector. Design tools can also be used to design and re-design commercial analog components for a wide range of industry electronics applications and transition.

REFERENCES:
1. Alexander, David R. et al. Design Issues for Radiation Tolerant Microcircuits in Space, NSREC Short Course, 1996.

2. Antao, B. A. et al. Computer-Aided Design of Analog Integrated Circuits and Systems, John Wiley & Sons New York NY 2002.

3. Lewyn, L.L., et al. "Analog Circuit Design in Nanoscale CMOS Technologies", Proceedings of the IEEE, 97(10), 1687-1714, 2009.

4. Williams, Jim (ed.) Analog Circuit Design, Butterworth-Heinemann Boston MA 1991.

KEYWORDS: analog, electronics, integrated circuits, low power, radiation-hardened, radiation-tolerant, nuclear technology, weapons, microelectronics, components

AF131-060 TITLE: W and V Band Satellite Transceiver

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop satellite transceivers with W-band (81-86 GHz) uplink and V-band (71-76 GHz) downlink capability.

DESCRIPTION: Demand for military satellite communication capability and bandwidth continues to increase. The current state-of-the-art for high-bandwidth satellite communication utilizes Ku and Ka-band frequencies. To avoid growing congestion at the Ku and Ka frequencies and to access a much broader spectrum, the Air Force is exploring the potential of operating satellite transceivers (also called transponders) in the W and V frequency bands. These much shorter millimeter wavelengths introduce unique technical challenges and opportunities. A disadvantage is the considerable uncertainty regarding channel propagation characteristics at these frequency bands. Potential advantages include recent advances in space qualifyable processors and millimeter-wave amplifier electronics.

The fundamental purpose of this research topic is to mitigate key technology risks to enable development of future satellite communication architectures using W-band (for uplink) and V-band (for downlink). This technology is intended to support future high-bandwidth satellite (geosynchronous) –to-ground communication. The specific field-of-study for this research is satellite communication (i.e., link analysis, encoding and decoding, transmission and detection, channel propagation effects, and electronics). The specific technology need addressed by this research topic is design and development of a satellite W/V-band transceiver.

Innovative designs and/or research activities are solicited to support development of a satellite W/V-band transceiver. Successful phase 1 and phase 2 efforts will provide tools and/or mature technologies to facilitate transceiver development. Proposers must demonstrate an understanding of satellite transceiver design, systems engineering, and implementation issues. The technical merit of a proposed transceiver concept or research activity must be demonstrated with respect to requirements resulting from a link analysis and should address a key technical risk or design problem.

An optimal transceiver design concept should minimize key performance parameters of size, weight, power, and cost, while maximizing transceiver performance (capacity, flexibility, and availability). The uplink frequency band is limited to 81 – 86 GHz, and the downlink frequency band is limited to 71 – 76 GHz. The design is not constrained to off-the-shelf components or space-qualified components. It should be assumed that the transceiver would be integrated onto an existing communications satellite spacecraft and bus. The contractor can make reasonable assumptions for the design of the companion ground transceivers.

PHASE I: The phase 1 effort must examine the many design trades available (i.e., power, aperture, channel bandwidth, electronics) and implementation risks. The phase 1 effort should identify key technology risks and design uncertainties, and develop mitigation strategies to address those issues in a phase 2 effort.

PHASE II: The phase 2 will focus on mitigating key technology risks identified in the phase 1 effort through software or hardware development, testing and demonstration. The phase 2 should result in an understanding of the key performance parameters and achievable performance for a practical realization of the revised transceiver concept.

PHASE III: Phase III Dual Use Applications:
Military Application: MILSATCOM systems would benefit from high capacity satellite uplink / downlink capability at W-band and V-band.
Commercial Application: There is growing commercial interest in W-band and V-band for terrestrial wireless communication.

REFERENCES:
1. Jebril, A., Lucente, M., Ruggieri, M., Rossi, T., “WAVE - A New Satellite Mission in W-band,” 2005 IEEE Aerospace Conference, pp. 870 – 879.

2. Rossi, T., Cianca, E., Lucente, M., et al., “Experimental Italian Q/V Band Satellite Network,” 2009 IEEE Aerospace Conference, pp. 1 – 9.

3. Cianca, E., Rossi, T., Yahalom, A., et al., “EHF for Satellite Communications: The New Broadband Frontier,” Proceedings of the IEEE, Vol. 99, No. 11, Nov. 2011.

KEYWORDS: Keywords: Space Communication, millimeter-wave, satellite transceiver

AF131-061 TITLE: W and V band Airborne SATCOM Transceiver

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop an airborne SATCOM transceiver with W-band (81 - 86 GHz) uplink and V-band (71 - 76 GHz) downlink capability.

DESCRIPTION: Demand for military satellite communication capability continues to increase. The current state-of-the-art for high-bandwidth satellite communication utilizes Ku and Ka-band frequencies. In response to increasing spectrum congestion and the need for more bandwidth, the Air Force is exploring the potential to use V-band satellite downlinks and W-band for satellite uplinks. These much shorter millimeter wavelengths introduce unique technical challenges and opportunities. A disadvantage is the considerable uncertainty regarding channel propagation characteristics at these frequency bands. Potential advantages include recent advances in space qualifyable processors and millimeter-wave amplifier electronics.

The key risk that will be addressed by this research topic is development of an integrated transceiver for an air platform (vehicle) such as an unmanned aerial vehicle that will allow it to communicate with a W/V-band satellite transceiver. The fundamental purpose of this research topic is to mitigate key technology risks to enable development of future air-to-satellite communication systems using W-band (for uplink) and V-band (for downlink). The specific field-of-study for this research is satellite communication (i.e., link analysis, encoding and decoding, transmission and detection, channel propagation effects, and electronics). The specific technology need addressed by this research topic is design and development of an airborne W/V-band transceiver.

Innovative designs and/or research activities are solicited to support development of a W/V-band transceiver suitable for an air vehicle. Successful phase 1 and phase 2 efforts will provide tools and/or mature technologies to facilitate transceiver development. Proposers must demonstrate an understanding of satellite transceiver design, systems engineering, and implementation issues specific to air vehicles. The technical merit of a proposed transceiver concept or research activity must be demonstrated with respect to requirements resulting from a link analysis and should address a key technical risk or design problem.

An optimal transceiver design concept should minimize key performance parameters of size, weight, power, and cost, while maximizing transceiver performance (capacity, flexibility, and availability). The uplink frequency band is limited to 81 – 86 GHz, and the downlink frequency band is limited to 71 - 76 GHz. The contractor can make reasonable assumptions for the space transceiver and size, weight, and power limits.

PHASE I: Phase 1 should focus on refining a transceiver concept, identifying key technology risks and design uncertainties, and develop mitigation strategies to address those issues in a phase 2 effort.

PHASE II: The phase 2 will focus on mitigating key technology risks identified in the phase 1 effort through software or hardware development, testing and demonstration. The phase 2 should result in an understanding of the key performance parameters and achievable performance for a practical realization of the revised transceiver concept.

PHASE III: Phase III Dual Use Applications:
Military Application: Air Force systems would benefit from high capacity satellite uplink and downlink capability at W-band and V-band.
Commercial Application: There is growing commercial interest in W-band and V-band for terrestrial wireless communication.

REFERENCES:
1. Jebril, A., Lucente, M., Ruggieri, M., Rossi, T., “WAVE - A New Satellite Mission in W-band,” 2005 IEEE Aerospace Conference, pp. 870 – 879.

2. Lucente, M., Stallo, C., Rossi, T., et al., “Analysis and Design of a Point-to-Point Radio Link at W Band for Future Satellite Telecommunication Experiments,” IEEE Aerospace Conference, 2011.

3. Cianca, E., Rossi, T., Yahalom, A., et al., “EHF for Satellite Communications: The New Broadband Frontier,” Proceedings of the IEEE, Vol. 99, No. 11, Nov. 2011.

KEYWORDS: Space Communication, W-band, aircraft transceiver, V-band

AF131-062 TITLE: Cooperative Networked GPS signal acquisition

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop GPS signal acquisition methods by cooperative networked techniques, describe trade-offs, develop concepts of operations for alternatives, and demonstrate operation.

DESCRIPTION: With GPS chipsets such as the CGM (common GPS module) mounted in communication devices such as cell phones or JTRS (joint tactical radio system) radios, the acquisition of GPS signals should be able to be shared among the devices that are in communication with each other. The purpose of this research is to develop methods to accomplish cooperative networked GPS signal acquisition, describe the trade-offs, develop concepts of operations for different alternatives, and demonstrate operation. Goals are to reduce the acquisition time (< 1 min) and enable direct acquisition of P(Y) signals.

The basic idea is to first synchronize all the participants to the time of one GPS/comm. device. This time is not perfectly known. The code (time) space to be searched is now divided among all the participants. Each participant searches his time space. Once one of the participants acquires the signal, he communicates the results to all the others that participated in the acquisition. The concept can be extended to including ephemeris in addition to GPS time. Those participants that do not need GPS signal can now shut off their devices to save battery power. Those participants who want the GPS signal can continue with the timing information supplied by the participant who acquired the signal. With this information on timing and on which satellite was acquired, all of the other participants can now quickly acquire the GPS signal since the code search space now is very small, saving battery power; the time to acquire can also be significantly shortened.

An additional benefit of cooperative networked GPS signal acquisition is signal acquisition at higher interference levels. The fact that the acquisition is distributed over many devices means that, if the total acquisition time is fixed, then each participant can dwell longer and thereby search over his code space segment to overcome higher interference levels. In addition to exchanging time information over communication links, each participant can exchange any additional navigation aid information such as approximate location, almanac, ephemeris, etc. (see Ref. 5).

Cooperative networked GPS signal acquisition has interference, fast time to fix, and battery power benefits for all applications: military, commercial and civil. Demonstrate using a prototype system that civil applications, particularly cooperative team efforts such as search-and-rescue missions where participants are both inside and outside buildings, are well suited for this technique.

PHASE I: Develop methods to accomplish cooperative networked GPS signal acquisition, describe the trade-offs, and develop concepts of operations for different alternatives. Prepare a report on the findings and develop a plan to demonstrate a cooperative networked GPS signal acquisition system.

PHASE II: Based on the recommendations, research outcomes and the plan developed in Phase I, develop a prototype system to demonstrate the benefits of cooperative networked GPS signal acquisition. Determine the battery power saved and the improved performance in high interference situations.

PHASE III: Cooperative networked GPS signal acquisition has interference, fast time to fix, and battery power benefits for all applications: military, commercial and civil.

Demonstrate using a prototype system that civil applications are well suited for this technique.

REFERENCES:
1. http://www.globalsecurity.org/military/systems/ground/jtrs.htm (JRTS reference).

2. http://www.gpsworld.com/gnss-system/gps-aep-55c-rest-story-we-went-source-9599 [mention of CGM (common GPS module)].

3. Kaplan, E.D. and Hegarty, C., ed, “Understanding GPS: Principles and Applications”, 2nd edition, Nov. 30, 2005. ISBN Number: 1-58053-894-0.

4. Misra, P, and Enge, P., “Global Positioning System: Signals, Measurements, and Performance”, 2nd edition, 2006, ISBN 0-9709544-1-7.

5. A-GPS: Assisted GPS, GNSS, and SBAS by Frank van Diggelen, 2009, Artech House, ISBN 13: 978-1-59693-374-3.

KEYWORDS: GPS signal acquisition, Networked systems, battery power

AF131-063 TITLE: GPS-denied Positioning using Networked communications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop and demonstrate algorithms and techniques to achieve accurate absolute positioning in a GPS-denied environment using cooperatively networked sensor nodes.

DESCRIPTION: The DoD is heavily dependent on the Global Positioning System (GPS) for worldwide military operations. The GPS signal, however, is subject to a variety of potential degradations, such as path loss (e.g., foliated or indoor environments), multipath (e.g., urban canyon or in-building), and interference (intentional or unintentional—the weak GPS signal is more vulnerable than other radio links such as in a communications network). Without GPS dismounted forces must rely on alternate navigation systems such as inertial navigation systems (INS) or have no available information at all. The navigation solutions from an INS that is small enough to be carried by a soldier degenerate in under a minute to the point where the data is no longer useful. These navigation solutions are needed to support the warfighter by not only providing a navigation capability but also providing the fundamental information necessary for situational awareness on the battlefield.

Navigation solutions could be enhanced by utilizing existing networked communications between several ground nodes. Dismounted forces often operate in small platoons where a communications network already exists. When some nodes lose their GPS signals, it is desirable to use the existing communications network to determine locations of such disadvantaged nodes. Unfortunately, traditional GPS-denied network positioning techniques such as Time of Arrival (TOA) or Time Difference of Arrival (TDOA) require extremely tight time synchronization among the sensor nodes; such a synchronization requirement is too stringent to be reasonably met by man-portable hardware due to SWAP constraints. Therefore, this topic seeks innovative methods to asynchronously estimate the absolute positions of those GPS-denied ground nodes by taking advantage of the existing communications network.

Commercialization potential: DoD applications include tactical squads operating under foliage, indoors, or in urban conditions, as well as similarly challenged unattended sensor networks. Commercial applications include personal handheld navigation including first responder navigation inside buildings, etc.

PHASE I: Develop algorithms, techniques, and a system concept for networked positioning system which overcomes adverse RF environments to allow absolute positioning and navigation to within 10 meters in a GPS-denied scenario. Demonstrate feasibility and quantify performance using analysis and simulations.

PHASE II: Develop a sub-scale demonstration of a positioning network, demonstrating the ability of a group of nodes to successfully navigate under GPS-denied conditions. Evaluate the feasibility of transitioning these capabilities into realistic tactical scenarios, including network integration with military radio terminals (e.g., JTRS).

PHASE III: This technology, if realized, would be of obvious immediate benefit to both DoD and commercial GPS users operating in challenging RF environments.

REFERENCES:
1. Hofmann-Wellenhof B. et al. (2004). Global Positioning System: Theory and Practice.

2. Major West Kasper, May 1 2004. GPS Vulnerability Testing. GPS World. http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=95325.

3. Chun Yang; Thao Nguyen, "Cooperative position location with signals of opportunity", Aerospace & Electronics Conference (NAECON), Proceedings of the IEEE 2009 National, 2009, Page(s): 18 - 25.

KEYWORDS: Global Positioning System, Urban Environment, Networked Positioning, TOA, TDOA, GPS Degradation, Digital Signal Processing Techniques

AF131-064 TITLE: RF Radio Communications Module for Secure GPS/GNSS-based Communications Navigations Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a low size, weight, power, and cost radio frequency module for a GPS / GNSS receiver to provide the capability of passing secure navigation and voice data among a localized network of users to find position in a degraded environment.

DESCRIPTION: Significant interest and research in recent years has been devoted to developing techniques for collaborative navigation based on a network of users operating together to maintain position awareness and navigation in situations where Global Positioning System / Global Navigation Satellite System (GPS/GNSS) signals are degraded due to environmental (i.e., terrain, foliage, multipath) and man-made factors (i.e., jamming, interference, urban canyon). The backbone of these approaches is the integration of GPS/GNSS receiver functions and possibly embedded sensors (e.g., accelerometer, gyroscope, compass, magnetometer) with a radio frequency (RF) communications module.

One of the objectives of the Military GPS User Equipment (MGUE) program is to integrate a low size, weight, power, and cost (SWAP-C) M-code capable GPS receiver with the Joint Tactical Radio System (JTRS) Handheld, Manpack, and Small Form Fit (HMS) radios. It is envisioned that these Comm-Nav receivers will leverage net-centricity to enhance the operational robustness and efficiency of warfighter positioning, navigation, and timing (PNT) capability and situational awareness. However, as a result of the growing demand by military users for both low cost and more user friendly GPS/GNSS receivers, there is greater emphasis on the use of commercial-off-the-shelf (COTS) GPS/GNSS receivers or military GPS receivers that do not require costly security protection features. To overcome some of the vulnerabilities and information integrity issues associated with these approaches, collaborative navigation among users using a communications network are being researched. While there are existing commercial solutions that provide a comm-nav capability to establish these types of networks, these have been shown to have significant security related issues which can be detrimental under battlefield conditions.

Innovative designs and / or research activities are solicited to support development and testing of a low SWAP-C RF radio communications module and associated antenna. The proposed concept or design should interface to the commercial GPS receiver serial NMEA data port and military receiver serial Instrumentation Port (IP) to transmit and receive specific navigation data. It should allow for localized secure networked communications of GPS/GNSS data and voice using AES 256 encryption between up to 30 users located within a 10 mile diameter circle that can be obstructed by terrain, foliage, or man-made structures. The system should provide a path for direct integration within a military or commercial GPS/GNSS receiver. Design goals should include limiting the module size to 1 sq-inch, module power consumption of less than 0.5 W, and equivalent isotropically radiated power (EIRP) with antenna of 2 W. The system should transmit and receive the JTRS Soldier Radio Waveform (SRW).

Proposed concepts should consider design issues including frequency band, digital modulation, data input/output method, data transmission rate, antenna characteristics and interface, error and data link processing protocols, and data/voice security.

PHASE I: Develop performance requirements and detailed design of the secure RF communications module and associated antenna. Provide simulations, analyses of proposed techniques, and recommended designs for implementation in a prototype system.

PHASE II: Build a prototype RF module to demonstrate the ability to network multiple GPS receivers and provide secure data and voice communication. The prototype module can interface to a commercial GPS receiver. Demonstrate the prototype in laboratory and field test trials with an ad hoc network of users to include real world effects like interference, multipath, and shadowing.

PHASE III: The ability to mitigate the effects of GPS signal degradation using collaborative navigation among networked users is a technique being used and considered for both civilian (e.g., disaster relief) and military (e.g., dismounted soldiers in urban environment) applications.

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1. Agarwal, V., Arya, H., and Bhaktavatsala, S., “Design and Development of a Real-time DSP and FPGA-based Integrated GPS-INS System for Compact and Low Power Applications,” IEEE Transactions on Aerospace and Electronic Systems, Vol. 45, No. 2, Apr 2009.

2. Serra, A., Nepa, P., Manara, G., and Massini, R., “A Low Profile Linearly Polarized 3D PIFA for Handheld GPS Terminals,” IEEE Transactions on Antennas and Propagation, Vol. 58, No. 4, Apr 2010.

KEYWORDS: RF communications, Soldier Radio Waveform, Communications-Navigation Receiver, GPS

AF131-065 TITLE: Integrated Fast-light Micro-inertial Sensors for GPS Denied Navigation

TECHNOLOGY AREAS: Sensors, Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: To demonstrate technology leading to an integrated approach to optically pumped atomic gyro/accelerometers with 1000X improvement in sensitivity.

DESCRIPTION: The Air Force is developing advanced technologies leading to small compact systems, which need micro-inertial measurement systems far beyond current state of the art.

Development of low size, weight and power (SWaP) components that can be used in an Inertial guidance unit that would maintain position location knowledge for long periods of time with only an occasional update from GPS would enhance long term location accuracy stability and provide greater reliability for satellites applications above the GPS constellation.

Recent developments have shown gyros, rate sensors, and other instruments based on optically pumping rubidium or cesium using single frequency semiconductor lasers precisely tuned to the atomic resonance transition. These experiments, including those using “cold atom” optics, have shown great potential, but have a long path to small system insertion. Recent experiments with “fast or superluminal light” have shown promising results to provide nearer term insertion with small footprint and an order of magnitude accuracy improvement.

Rubidium and cesium devices have shown promise for compact, low SWaP microsystem applications but are a long way from transition into practical, ruggedized 3-axis flight and ground system applications. Basic research experiments as derivatives of chip-scale atomic clocks have shown that hybrid integrated optical-fast light devices could potentially have large expensive laser-ring-gyro performance in sizes as small as 1 cubic centimeter.

Ring laser structures with anomalous dispersion (i.e., a fast-light medium) are examples of approaches to realize a rotation sensor with a sensitivity enhanced by a factor as high as 10E5 for experimentally accessible parameters. It may also be possible to use this approach to realize an accelerometer, with a similar enhancement in sensitivity. Given conventional optical accelerometers can achieve a sensitivity of less than 1micro-G/root-Hz, it should thus be possible to reach a sensitivity as high as 10 pico-g/ root-Hz. Furthermore, since the enhancement is non-linear, the device should have a very high dynamic range, and should also be able to sense large accelerations as well.

Recent breakthroughs in single frequency semiconductor laser diodes and bidirectional amplifiers have enabled a conceptual integration into a single laser driven multi-axis inertial sensor with sense nodes on sub-centimeter-cubed scale. Miniaturized, frequency-agile, robust laser systems that can operate autonomously while locked to atomic transitions with prescribed offsets up to 10 GHz are also needed. These lasers are marginally available today from an offshore supplier, but DoD users and other contacts report long delivery times, low reliability, and frequent failure to meet published specifications. Emerging domestic suppliers must be developed to ensure stable sources of supply of these precision lasers.

The SBIR topic solicits novel concepts and component technologies in design, development, and demonstration of components, subsystems, and systems for an integrated fast light optical device atomic/quantum 3 axis transducer for rotational and linear inertial sensing (Inertial Measurement Units).Sensitivities approaching the limits discussed above (10 pico-g/root-Hz translational) as well as allow for a high dynamic range (10’s of milli-g’s) allowing detection of both very small (e.g., solar radiation pressure, orbital drag) and very large (e.g., thruster firing) events. Very low SWaP implementations are desirable to minimize impact to hosting spacecraft (100s of cm3). The sensing system should be able to withstand the space environment, acceleration, and vibration environments of launch and be able to have long term endurance for orbital environments (300kRad Si Gamma, 300kRad Proton @63MeV, operational temperatures between - 30 and +60 °C).

PHASE I: Conduct experimental and analytical efforts to demonstrate proof-of-principle of the proposed technology and concept. Determine expected performance through extensive analysis/modeling effort. Identify technical risks and develop a risk mitigation plan. Investigate integration of lasers, modulators, and environments.

PHASE II: Design, develop, and characterize prototypes of the proposed technologies and demonstrate functionality. Demonstrate feasibility and engineering scale-up of proposed technology; identify and address technological hurdles. Demonstrate applicability to both aircraft and spacecraft environments, including vacuum, cryogenic operation, and long term radiation exposure.

PHASE III: Military App: Provide an inertial reference for small spacecraft at GEO for which GPS signals may not be available. Commercial App: Develop and manufacture the micro-optical atomic inertial subsystem or system developed in Phase II. Incorporate on commercial satellites to reduce power and weight.

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KEYWORDS: Inertial navigation, attitude, MEMS, atomic gyro, integrated optics, grating out coupled single frequency laser diode, integrated optics, attitude determination, Micro Air Vehicle, Integrated Targeting Device

AF131-066 TITLE: <u>Multiband Metasurface for Reduced Antenna Footprint and Jamming Mitigation</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Research and develop a multiple-band, electromagnetically-tailored "meta" surface to reduce overall antenna payload footprint and mitigate effects from unwanted RF signals.

DESCRIPTION: Satellite antenna systems sometimes utilize telecommunications links which transmit/receive (T/R) through separate apertures to prevent co-site interference. This increases the footprint and weight necessary for an antenna payload. Furthermore, antenna location must be carefully chosen on the spacecraft to prevent degradation in performance due to this "self-interference". This topic seeks to develop an engineered surface that would allow operation of multiple RF bands through a single antenna aperture while maintaining performance under influence of unwanted signals. This would effectively allow multiple T/R antennas to reside in one physical location. Design benefits include reducing complexity, redundant support systems, weight and total footprint. The performance benefit is to mitigate effects from unwanted signals—both intentional (jamming) and unintentional (interference)—which can include receiver desensitization, signal masking, spoofing and degraded anti-jam capability. As a result of both, this also would allow satellite designers greater freedom in choosing antenna payload location, free up valuable spacecraft real estate, and enable robust small satellite antenna systems.

Electromagnetically (EM)-tailored surfaces, also referred to as "frequency-selective surfaces" or “metasurfaces” in recent publications, offer a means to control the electromagnetic properties of an EM wave that permeates its surface. The primary functionality of this surface is to create frequency band stops or band passes; the frequencies affected are dependent on the geometry and design of the unit cell’s periodic surface. This effectively isolates one antenna from another. The U.S. Navy has researched the field of metasurfaces to create a gimbaled, multi-layered antenna system for their capital ships that can simultaneously operate in L, S, and X-bands—reducing the overall footprint and weight, but increasing its overall size in free space. The freedom to create this large system of arrays or reflectors in free space is not a practical design for space satellite systems, so an alternative solution is needed.

The key characteristic of a multi-band metasurface is to allow transmission and/or reception of signals whose bandwidths do not overlap significantly, thereby reducing effects of co-site interference. Proper tailoring of the design should also inherently introduce some level of protection from intentional broadband jamming. It is required that this be a conformal solution that adds negligible size/weight/power and works symbiotically with the antenna structure, as opposed to a standalone technology or payload. Low-power active control over bands of operation is of interest, but passive solutions are encouraged as well. Proof of design scalability is of strong interest, as this would give rise to a modular toolkit for SATCOM and ISR payload developers. Proposal must address the manufacturing and survivability issues and in particular consider the harsh launch and operating environments that satellite systems undergo. Heavy modeling and simulation for initial investigation of design approaches is highly encouraged.

PHASE I: Examine EM-tailored surface for AEHF comm with threshold of 44 GHz up-link along with 60 GHz sat-2-sat comm and an objective to hit up-link, cross link and 20 GHz down-link. Provide analysis demonstrating proof-of-concept of single aperture operation of multiple RF bands and material selection suitable for the space environment. Assess active tunability and control mechanisms (if applicable).

PHASE II: Refine concept from Phase I and demonstrate critical performance via experiment. Testing to be done includes EM property characterization, mechanical property characterization, and suitability to the space environment (any orbit). Demonstrate un-degraded or improved operation in the presence of appropriate threats, i.e. an interference/ jamming source.

PHASE III: Military App: Immunity/mitigation of negative effects of unwanted signals on military space-based antenna payloads. Allows for unprecedented antenna payload design freedom. Commercial App: Same application for commercial satellite communications antennas.

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KEYWORDS: Interference, Jamming, Multiband, Metasurface, FrequencySelectiveSurface

AF131-067 TITLE: Software-Only Front-End Processors for Satellite Command and Control

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a reconfigurable software-only front-end system for satellite command and telemetry processing.

DESCRIPTION: Technology breakthroughs have drastically increased the complexity of today's satellites, with some satellites having upwards of 20,000 satellite telemetry points. In addition, communication technology has increased the data throughput capability across satellite links. The net effect is that the amount of satellite data that must be downlinked to the ground and de-commutated has increased drastically. Ground telemetry processing technologies have not kept abreast of the corresponding technologies enabling much greater data throughput. Specialized expensive computer hardware is thus often needed. Meeting these additional data demands is often not as simple as buying more expensive and faster computer hardware. What is needed are more innovative software approaches for performing telemetry de-commutation implementation of these approaches with reusable systems in order to lower development and operations costs. In this time of reduced budgets, many organizations are seeking affordable and flexible command and control (C2) systems in order to provide mission support for a variety of satellites. One such system is called the multi-mission satellite operation center (MMSOC) which is currently supporting a number of DoD missions. The mission suite is rapidly being expanded to include a variety of new missions from the large-scale programs to the tiny CubeSats. The variety of missions present daunting challenges: how to affordably host these missions while providing highly-tailored business models. Many new missions have need of very small equipment footprints and low acquisition cost. Scalability and portability of satellite C2 systems such as the MMSOC are overcoming the aged concepts of large, fixed C2 facilities.

Satellite C2 systems, particularly those which must interface with the AFSCN, require expensive front-end processors (FEP) to process the command and telemetry streams or packets. Each FEP is comprised of a dedicated processor which requires its own space, power, and HVAC. The use of dedicated FEPs in satellite C2 systems was necessary. The real-time demands of processing the streams and precisely time-stamping the data have required a dedicated CPU. With the proliferation of multi-core CPUs operating in GHz cycles, however, there is now no reason a FEP cannot be based entirely in software and hosted on the same server as the rest of the satellite C2 system. A software-only FEP can liberate satellite C2 systems to be hosted on extremely small and affordable equipment footprints. They can also enhance super-scalability, redundancy, and failover capabilities by having any number of FEP processes running on demand. Of particular interest is the capability to run multiple software-only FEPs from a single multi-core computer. While industry has experimented with software FEPs, they have yet to be proven in the demands of a combat support system.

Innovative reconfigurable low-cost software solutions are sought that will enable processing of large volumes of satellite telemetry data.

PHASE I: Conduct feasibility studies/technical analysis/simulation/proof-of-concept demonstration software-only FEPs. The FEPs should demonstrate the cost savings over their hardware counterparts, to include typical life-cycle costs. Analysis of the performance and performance degradation over hardware solutions should be shown. Industry standard protocols such as CCSDS and WAN IP should be considered.

PHASE II: Using the results from Phase I, construct and demonstrate use of a software-only FEP in command and control of a simulated or, if available, an experimental satellite. Demonstrate launch of FEP service on demand. Demonstrations should consider items such as: having multiple FEPs running on a multi-core CPU; and hot handover of satellite contacts between two FEPs on a single multi-core computer.

PHASE III: Military Application: A modular software FEP is considered for super-scalable/affordable future military satellite C2 systems.

Commercial/Civil Application: Lowering the cost of NASA/commercial/academic space experimentation by eliminating specialized hardware in the mission control system.

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KEYWORDS: Telemetry, Tracking, and Commanding (TT&C); Satellite Command and Control (C2)

AF131-068 TITLE: Retrieving Cloud Ice Water, Cloud Liquid Water, and other Cloud Parameters from GPS Radio Occultation and Satellite Microwave Imager/Sounder in Heavy Precipitation

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop techniques to improve the diagnosis and forecast of cloud parameters associated with the transmission and emission of polarized radiances through all weather conditions, including heavy precipitation.

DESCRIPTION: Remarkable advances in remote sensing technology have occurred since the first applications of the formal solutions of radiative transfer to cloudy atmospheres (for example, Liou, 1973). The capability of current and future remote space-based sensors to measure polarized radiative information correlates well with the theoretical development of polarized radiative transfer in the vertically-layered atmosphere (Weng, 1992). Microwave emissions from precipitating clouds associated with moderate precipitation rates penetrate non-precipitating clouds. These emissions can be detected and measured by satellite microwave sounding instruments. Such passive measurements at mm-wave frequencies can be used to derive vertical profiles of cloud liquid water content (CLW) and cloud ice water content (IWC) (Weng and Grody, 1994); (Weng and Grody, 2000).

Recent studies have shown that GPS radio signals are sensitive to clouds, as well as refractive bending, in heavy-precipitation conditions (Lin et al, 2010). Extracting IWC and CLW from GPS Radio Occultation (GPS RO) (in addition to temperature and humidity) in heavy precipitation conditions is a unique and un-explored area. GPS RO can complement satellite passive microwave observations as well as other types of sensor measurements (Lin et al, 2010). The new capability of COSMIC-2 (Cook et al, 2011), where a phased array receiver is employed to increase the gain in the lower troposphere and improve GPS RO measurement accuracy down to the surface, will also allow low-level cloud parameters to be diagnosed. While this may be a good approximation in most cases, it could fail in heavy precipitation due to attenuation over long slant paths at frequencies near 1.1 GHz.

To produce the CLW, IWC, and other cloud parameters, a numerically-based data assimilation system capable of using various measurements from satellite remote sensors to produce gridded spatial distributions of cloud variables using forward integration may also be desirable. Such a system should be adaptive and capable of handling satellite radiances sensed with various orientation angles. A variety of theoretical and technological considerations can also be applied relating to scattering effects of clouds on the remote measurements. An advantage to using a data assimilation system is the ability to produce gridded fields of the cloud parameters. While the data assimilation system is not required, proposers might also wish to consider this.

AFRL Relevance: AFRL (Space Vehicles Directorate) maintains the MODerate Resolution Atmospheric TRANsmission Model (MODTRAN). MODTRAN is used in a myriad of critical DOD remote sensing applications (Anderson et al, 2012). MODTRAN is also used by the armed services of major U.S. allies. Retrievals developed through this SBIR topic can be used to improve MODTRAN's diagnosis of scattering, absorption, and emission associated with clouds and precipitation.

PHASE I: Develop a retrieval system design which can retrieve the cloud parameters needed for polarized radiative transfer models. Deliverable: Demonstrate the physical applicability and accuracy needed to meet radiative transfer model requirements.

PHASE II: Complete, implement, and assess the system used for cloud parameter retrievals. Validate and verify cloud properties retrieval according to microphysical criteria and usability in radiative transfer models. Deliverable: Cloud parameter retrievals which also demonstrate the suitability for using microwave satellite and GPS RO observations to monitor the global cloud distributions.

PHASE III: Improved numerical weather prediction model initialization and parameterization. (2) Performance assessment of RF communications networks. (3) Improved characterization of polarized rad transfer through cloudy atmospheres.Similar applications for Commercial satellite industry is envisioned.

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KEYWORDS: Clouds, remote sensing, radiative transfer, microphysical parameters

AF131-069 TITLE: <u>AFSCN Mission Planning and scheduling tool</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a means to automatically generate an optimized satellite ground resource utilization schedule capable of flexibly fusing electronically-generated routine and real-time priority access requests.

DESCRIPTION: The Air Force Satellite Control Network (AFSCN) is a global network that supports 170+ Earth-orbiting satellites with 16 ground-based antennas of different sizes. The AFSCN is in need of an automated intelligent real-time planning and scheduling tool that will aid in the allocation of antenna and communication resources globally and locally. The challenge is to develop a more intelligent mission planning and tasking system, which is capable of looking at this problem under a new paradigm through innovative research and development. The innovative solution must address current challenges within the system which include the following three challenges. (1) The current solution is based on a concept of centralized scheduling. Distributing the scheduling/de-confliction reasoning process out toward the individual Space Operations Centers (SOCs) may provide a more cooperative schedule in a more timely fashion. This issue is further tested by the fact that communication channels between the SOCs provide limited bandwidth for information transmission. (2) Resource needs are dynamic and interrupted by real-time changes required by launch slips, ground equipment failures, and in-space emergencies. These require extremely rapid de-confliction (seconds to minutes), while minimizing changes to the existing schedule, especially in the nearest term aspects of the schedule (first few future hours). A system which can intelligently produce a notion of contingencies, perhaps based on learning acceptable solutions from past data, is needed to more intelligently create an acceptable "contingency" plan. (3) Satellite operations for sustainment and maintenance are extremely costly. These costs include the equipment required for satellite contact supports, personnel and the assets themselves. Presently significant time (almost a year) is needed to properly train and field an expert scheduler. A system which could intelligently interpret satellite telemetry/real time data feeds and fuse this information with: the existing schedule, asset owner objectives, etc, would provide significant saving costs. For example, the system could dynamically cancel unneeded contacts, reduce contact time, etc. All these actions are inevitably linked to costs.

The detailed challenges described above are similar in aspect to those presented to Intelligent Transportation Systems; space systems are more complex, however, as the resource management components involved are highly variable. This leads to combinatorial explosion in the complexity of the problem. Innovative research in the areas of intelligent planning systems, multi-agent planning systems, machine learning or perhaps intelligent agents or embodied agent approaches may apply. The solutions must be able to quantitatively show time and cost reduction. The current system operates on a 24 hour cycle requiring a substantial amount of labor. The desired system would operate within minutes to seconds and show dynamic adaption to real-time events.

This tool will pave the way for a new paradigm of intelligent AFSCN Mission Planning.

PHASE I: Perform requirements analysis and develop preliminary design. Indicate operating environment and language to be used, functional and process flows, data associations, and inputs/outputs. Vendor must be able to quantify the benefit of the proposed solution.

A prototype delivery is encouraged. Validating the tool using simulated or actual satellite contact data is also encouraged.

PHASE II: Develop the Mission Planning Tool and show its robustness for mission adaptation and model editing. Validate the tool using simulated or actual satellite contact data for data from at least two ground stations. Document the details of the product and results to facilitate transition to acquisition.

PHASE III:
Military: The desired AF Program of Record would be the ESD 3.0 system. However, could provide wide applicability to many space mission systems.
Commercial applications are anticipated due to similarity between the military and commercial space operations;may be used by NASA or NOAA.

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KEYWORDS: Resource management, disparate resources, network of antennas, algorithm testbed, Mission Assurance, Mission Assessment, mission performance analysis, long term trending & analysis, optimized scheduling

AF131-070 TITLE: High Compression of Infrared (IR) Data

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop an 8x compression algorithm for space infrared data.

DESCRIPTION: While Infrared (IR) space surveillance data is typically massive, it must reach Warfighters in the field via a very narrow (56k) communication channel. By implementing 8x data compression algorithms it is anticipated that a larger Warfighter audience can be reached. Additionally, more data could be delivered via the downlink while simultaneously reducing the required bandwidth loads on the core Air Force network and Communication assets.

This solicitation seeks an innovative 8x compression algorithm for space IR data which exceeds the standard Rice algorithm compression ratio [1]. We cannot afford to lose critical information to lossy compression; accordingly, we require a loss-less approach. It is also desirable that the compression algorithm not consume excessive amounts of processing power since it must be used on a satellite having stringent power and computer processing limitations.

PHASE I: The Phase I work should include development of an efficient compression algorithm and representative software to demonstrate proven performance. There is no hardware requirement.

PHASE II: The Phase II program should develop and deliver a turn-key source code that is in compliance with DoD regulations [2] for use in a DoD system. Shall include testing against real OPIR data for compression efficiency testing.

PHASE III: Military Application: IR specific compression algorithms can be used for air or land based surveillance equipment by any DoD organization. Commercial Applications: IR specific compression algorithms can be used for air or land based surveillance equipment.

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KEYWORDS: IR data, compression algorithm, source code, bandwidth, warfighter

AF131-071 TITLE: Space-based, Low-weight, Low-volume MWIR and SWIR Interferometer IR Sensor

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a low weight and low volume hosted infrared sensor (including telescope and solar baffle) based on interferometer principles.

DESCRIPTION: Space Based Infrared (IR) payloads have been proven exceptionally useful in applications such as missile warning, missile defense, technical intelligence, and battlespace awareness; however, they tend to be very large and heavy. In order to host an IR payload effectively on a commercial or government satellite bus, both weight and volume of the IR payload must be reduced. Interferometry can be used to combine several smaller sensors to replace a large one, while preserving some desirable capabilities [2,3,4].

This solicitation seeks innovative IR (MWIR and SWIR) interferometer based payloads to reduce weight and volume. Ideally, significant reductions would be made to both cost and size of the payload, scaling it down to a hosted payload volume. The rectangular outer envelope should not exceed 24 inches in any dimension. The main IR spectrums of interest are the atmospheric windows [1]. Multi-spectral capability is desired. The sensitivity should be maximized for a geostationary orbit. There shall be at least three IR sensor assemblies on a payload. No foreign nationals can work on this project.

The technology shall be capable of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and five years in Low Earth Orbit (LEO) after up to five years of ground storage.

PHASE I: During Phase I, concepts for IR sensors based on interferometry should be further developed. This should include mechanical and optical models and accompanying SWAP, strength, and optical analyses. All sub-systems, including signal processing, should be identified and evaluated. If low cost is claimed, a target cost should be identified and plans to meet this cost should be described.

PHASE II: Work should include fabrication of a representative ground based prototype to prove performance. The Phase II program should develop the process, procedures, and costs required to fabricate, test and deliver multiple space flight ready individual IR sensors (interferometer) hostable payloads. Verification of these procedures through launch and duration tests in a relevant (on-orbit simulated) environment should be considered.

PHASE III: The Phase III work will integrate sensor into Program of Record or Space Test Flight. Small IR sensors with high performance have applications in UAVs, other airborne platforms, commercial IR surveillance satellites, and space telescopes (NASA).

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KEYWORDS: interferometry, infrared sensor

AF131-072 TITLE: Game-Theory Enabled Radio Spectrum Management and Waveform Adaptation for Advanced Wideband Satellite Communications

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Advanced game-theoretical frameworks and approaches for spectrum sensing and management in wideband satellite communications systems; Active countermeasures for adaptive RF interference and adversarial jamming.

DESCRIPTION: Satellite communications systems and hybrid space-terrestrial systems are essential components for improved warfighting capabilities and enhanced defensive control over complex collaborative missions. Current military satellite communications infrastructure is multi-tiered to cater to different communication needs, ranging from wideband transmissions (i.e., supporting multi-channel, secure voice, and high data-rate communications) and protected systems with anti-jamming features and covertness, to narrowband systems for small and mobile users. To support growing user communication needs, the wideband segment of the military satellite communications will be essential to minimize user-to-user latency, increase wideband data rates and extend communications reach. In wideband satellite communications systems the unprecedented complexity and unpredictability of the operating environments, aggravated by electronic attacks and countermeasures, makes it crucial to develop cognitive spectrum management and agile waveform adaptation solutions that are not only context-aware and capable of learning and probing for subscriber distributions, quality of services, mission priorities and traffic patterns, but also are agile in waveform adaptation to provide active countermeasures for persistent and adaptive RF interferences and adversarial jamming.

In this SBIR topic call, new approaches on pragmatic aspects of multiplayer game theory that would handle imperfect information, dynamic group formation, deception, non-stationary, and hidden objectives of opponents are particularly sought for cognitive radio spectrum management and waveform adaptation. Areas of science discovery and technology development include but are not limited to: (1) modeling of learning, interactions, and rational and non-rational strategies in the dynamics game context of cognitive radio spectrum management and anti-jamming countermeasures that can efficiently utilize satellite communication bandwidth, coherently interface with terrestrial systems, and effectively counteract persistent and adaptive jammers and interferences; (2) characterization and analysis of different game values subject to asymmetric information possessed by adversarial radios; and (3) scalable, approximate, algorithmic techniques that can potentially assess implications of cognitive radio decisions. For effective gaming, wideband spectrum sensing and cognition have to be integrated in order to gain awareness of the complex radio propagation environments and quickly capture the network dynamics and adversarial activities as well. In addition, adaptive waveform designs shall be able to perform autonomous frequency band selection and exploit time-delay propagation characteristics and antenna selectivity. Particular frequency radios of interest include SHF (Super-High Frequency) and EHF (Extremely-High Frequency). Other operational performance measures may include: i) protection and security with active anti-jamming, low probability of detection and interception and ii) survivability through space and terrestrial segment threats without damages and operating through threats without interruption. Lastly, transmitted signal powers, gains of antennas, and efficiency of receivers that all have impacts on throughput capacity can at least be planned for as a consideration.

PHASE I: Identify feasible game-theoretical approaches for joint waveform adaptation, cognitive spectrum sensing & management in hierarchical spectrum sharing games with primary users, secondary users, persistent jammers and asymmetric information structures. Develop anti-jamming strategies by game-based means of frequency diversity, hybrid satellite-terrestrial networking & physical medium access layers.

PHASE II: Refine Phase I results that make dynamic spectrum sharing and waveform adaptation games practical and relevant for analyzing non-rational decision making. Demonstrate a proof of concept on spectrum sharing throughput and susceptibility to jamming. Optimize the deployment of anti-jamming strategies based on sensitivities and biases of host communications policies. Conduct performance assessment on throughput capacity & channel capacity whether or not active anti-jamming measures are implemented.

PHASE III: If successfully developed, the technology can potentially reduce technology risks in support of the Advanced Extremely High Frequency satellite systems to provide worldwide, secure, survivable, and jam-resistant communications for high-priority military ground, sea, and air assets.

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KEYWORDS: Satellite communication infrastructure, hybrid satellite and terrestrial systems, wideband spectrum sensing, channel capacity, throughput capacity, threat survivability, cognitive radios, waveform adaptation, distributed implementations, protection, prevention, active anti-jamming, performance assessment, game theory

AF131-073 TITLE: Radiation Hardened Low Power Variable Bandwidth/Resolution Sigma Delta Converters

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Identify concepts and architectures for radiation hardened sigma delta ADCs (analog to digital converters) and DACs (digital to analog converters) for application in satellite control systems.

DESCRIPTION: Satellite systems rely on numerous servo systems to control antennas, thrusters, gyros, and many other mechanical functions. Critical elements in many of these systems are high resolution ADCs and DACs. Typically, these applications require relatively low bandwidth (<10 MHz) but need high resolution (16 to 22 bits) with high signal to noise ratio (114 db). In many cases, there are opportunities for trading off resolution and bandwidth with higher precision available for lower bandwidth and vice versa. As with all space electronics, there is significant benefit in reducing the size, weight, and power in the ADC and DAC. Proposals are requested for sigma delta architectures for either ADCs or DACs that are optimized for space applications. The proposals shall indicate the provisions that have been incorporated to address the unique requirements of space applications and the environmental challenges of multi-year space missions.

General requirements for the rad hard, low power, variable bandwidth ADC or DAC: The ADC or DAC proposal shall address the following: (a) the development of a design architecture capable of variable bandwidth/resolution while maintaining low power operation in a space environment; (b) the design and fabrication of either an ADC or DAC with the targeted characteristics; (c) provisions for radiation hardening to the space environment (total dose hardness > 300 krad(Si), no single event latch-up, no single event functional interrupts, and error management for single event upset from heavy ions or protons).

PHASE I: The contractor shall develop an architecture for an ADC or DAC consistent with the requirements above. The effectiveness of the proposed architecture shall be demonstrated via simulation. The approach to design, fabricate, and test a radiation hardened version shall be clearly stated.

PHASE II: The contractor shall design, fabricate and test either an ADC or DAC based on the architecture developed in the phase 1 activity. Testing shall include electrical verification of performance and demonstration of the radiation hardness.

PHASE III: This research supports a broad range of military space, ground and aviation applications which utilize digital signal processing. A robust amount of commercial applications will result in above areas.

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KEYWORDS: rad-hard electronics, integrated circuits, analog, analog to digital converter, sigma delta, digital to analog converter, digital processing, microelectronics

AF131-074 TITLE: Ultra-efficient Thermoelectric Cooling Module for Satellite Thermal Management

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop an ultra efficient thermo electric cooling module (TECM) to manage satellite payload waste heat and/or convert waste heat into electricity.

DESCRIPTION: Recent DARPA sponsored research points to the potential for a revolutionary advance in solid state cooling efficiency due in part to developments in thin-film cooling devices, which have been shown to exhibit a two to three times efficiency advantage over the current generation of TECM’s. As the burden on digital processing increases to accommodate ever increasing satellite payload functionality, site-specific cooling will play a crucial role in thermal management in future payloads. While terrestrial systems can sometimes use fluid based cooling systems, reliability concerns with potential for fluid leaks in space-based systems will likely drive future cooling designs towards solid state cooling approaches. The purpose of this topic is to support system level design and development of an integrated, distributed thin-film, thermoelectric cooling system suitable for removing waste heat in satellite payloads, including the sensor, control and actuators. Design goals include minimization of the board area and weight dedicated to cooling, capacity to transfer heat from high wattage devices, cooling efficiency, flexibility to support a broad range of board layouts, compatibility with commonly used Printed Wiring Boards

(PWBs) in military satellite payloads, reliability to support long term (>15 year) satellite missions, ability to withstand long term exposure to the geosynchronous earth orbit space environment.

Specific technical requirements that must be met include:
- Accommodate component heat loads of at least 0.5 W/cm^2 (threshold) and up to 50 W/cm^2 (objective)
- Provide cooling capacity of at least 5 W (threshold) and up to 150 W (objective) per component
- Maintain IC hot spots less than 86 ºC (threshold) and 76 ºC (objective)

All aspects of the thermal control system must be compatible with the space environment and conform to space qualification requirements including high vacuum, microgravity, radiation, atomic oxygen, low outgassing, and high launch loads. Proposed technologies will be judged based on their thermal performance, reliability, cost, and mass, as well as on the integration complexity/cost with respect to current board/box/component designs. Proposers are encouraged to team with system integrators and payload providers to ensure applicability of their efforts and to provide a clear technology transition path.

PHASE I: Design distributed thermoelectric cooling system suitable for use in space based payloads and validate through modeling and simulation.

PHASE II: Fabricate a prototype distributed system, including sensors, actuators, controller, and TEC devices and characterize for cooling capacity, efficiency, weight, power, reliability, radiation tolerance and operating temperature range.

PHASE III:
Military products that benefit from light weight TEC systems include space electronics such as digital, analog and mixed mode assemblies.
Commercial products that benefit from TEC systems include automotive industry.

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KEYWORDS: thermoelectric, cooling, junction temperature, thermal conductivity, thermal resistance, thermal management, refrigeration

AF131-075 TITLE: <u>Hosted Payload Support Technologies</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop technologies to support the effective use of hosted payloads on military and/or commercial satellite systems for DoD applications.

DESCRIPTION: There is an increased interest in the so-called "hosted payload", which refers to the ability to add a secondary payload(s) opportunistically to a spacecraft having an otherwise specific, dedicated primary purpose. Hosted payloads are being explored on commercial, military, and civil spacecraft platforms. A DoD-sponsored hosted payload was recently demonstrated by DoD in the Commercially Hosted Infrared Payload (CHIRP) mission as a viable method of deploying a payload at a fraction of the cost (10-25%) of the cost of developing a dedicated mission to field the same payload. It is intuitive that cost savings can accrue when the bulk of the infrastructure of spacecraft, launch, and sometimes ground operations and communications burden can be borne by a primary user. As such, the hosted payload concept is attractive both to the payload developers as well as the prospective sponsors, who can use the revenue generated by a secondary payload to defray expenses in the overall development of a primary mission. While it is not likely the hosted payload will service every mission concept, it could be very attractive for a majority of potential mission candidates.

The notion of a "hosted payload" is in a sense not a new idea. The idea of multiple payloads on a single satellite is almost as old as the "artificial satellite" itself. Over the years, secondary and tertiary payloads have been added to spacecraft missions. More recently, ideas such as the space plug-and-play architecture (SPA), the Self Awareness Space Situational Awareness (SASSA) and (in Europe), Space Avionics Open Interface Architecture (SAVIOR) have all been introduced as concepts for standard interfaces, and some of these may have applicability. However, any prospective standard for hosted payloads must meet a number of key requirements: (1) open interface specifications for power, mechanical, thermal, and informatics; (2) the need to support high-bandwidth (e.g. > 100 Mbits/sec); (3) the ability to accommodate high-power payloads (> 100W), (4) the need for sophisticated command/control/telemetric support for a rich, diversity of prospective payload types; and (5) the ability to support strong encryption / multi-level security protocols. This latter requirement is a special challenge to hosted payloads, since commercial spacecraft represent at the same time an abundant opportunity for fielding missions and a concern for the comingling of critical payload data and unknown varieties of primary bus command, control, and information products. None of the contemporary concepts (e.g. SPA, SASSA, and SAVIOR) have to this point sufficiently addressed these requirements. An indirect (but equally important) challenge in creating a hosted payload concept to implement a solution that adds very little size, weight, and power (SWAP) overhead to the primary, ideally less than 2 per cent of dry mass and end of life power consumption of the host.

Other auxiliary concerns relating to commodization of the hosted payload is (1) the lack of tools dedicated to managing a database of known hosted payload opportunities and surveying/analyzing the suitability of candidates to the purposes of particular user applications and (2) toolkits for easily integrating the mission products of hosted payloads into typical ground system infrastructures.

Addressing these barriers will likely save cost (estimates range from 50-90%). The standardization is likely to improve mission assurance by regulating the form and format of the payload power, data, command, and mechanical interface, reducing uncertainty and simplifying the integration process (the effort of connecting a hosted payload to available hosts). Presumably, the standardization would take hold on both sides of the “problem”, the host and the payload. Addressing the second barrier would promote a widespread use of the hosted payload concept in future missions and spur increased availability by prospective hosted payload offerors.

PHASE I: Provide solutions that demonstrably meet the stated requirements for hosted payloads. Standard interface/analysis tools are examples. The interface addresses power/electrical interface/synchronization with a data protocol to be concise/flexible for variable payloads. Tools involving computer-aided design/modeling/simulation/analysis with consideration of enterprise resource planning must explore.

PHASE II: Offerors must provide convincing progress towards a transitionable solution based on the ideas explored in the Phase 1 activity. Partnerships with others and identification of additional sponsorship is encouraged.

PHASE III: Military Applications: As demonstrated in the CHIRP mission, hosted payloads make sense for DoD. Commercial Applications: Through standardization, the concepts addressed in this topic are equally useful to commercial payloads and commercial sponsors providing hosted payloads as a “service”.

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KEYWORDS: hosted payloads, standard interface, radiation-hardened electronics, computer-aided design

AF131-076 TITLE: Improved Estimation Approaches for High-Accuracy Satellite Detection, Tracking, Identification and Characterization

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop improved algorithms capable of fusing and exploiting existing and/or planned space surveillance data sources to improve ability to detect, track, identify, and characterize man-made space objects.

DESCRIPTION: Detecting, tracking, identifying, characterizing, and cataloguing of space objects is a difficult Air Force mission that involves maintaining a catalog of over 20K+ objects. This is currently accomplished by exploiting a disparate network of sensors having a variety of missions other than space surveillance. No single object is observed persistently given the scarcity of sensors and priority-based tasking. The sparcity of data requires improved methods of data association, namely the ability to confidently ascribe measurements to unique objects. Given the increasing number of launches and proliferation of space debris, the task of identifying and discriminating space objects is becoming more challenging. Most space objects have unknown size, shape, material properties, and rotational dynamics, further complicating the issue. The collected data set is derived from both radar (range) and optical (line-of-sight or bearings-only) sensors. Along with these data, object radar cross-section as well as radiometry in one or more wavelengths is available yet not fully exploited for its fused information content. In essence, the problem can be generalized to one of multi-sensor/multi-target tracking with probability of detection less than one and often times no a priori information. The space object dynamic and model parameter state of both continuous and discrete random variables is hidden/unknown and only observed indirectly via the reduction of non-linear, corrupted, noisy, and biased measurements. Moreover, the current representation of space object ambiguity is artificially constrained to that of Gaussian distributed errors.

Thus, the proposed work needs to achieve a number of goals: (1) improve the ability to fuse and exploit existing data sources to detect new and/or lost space objects; (2) to identify newly detected objects and allow measurements to be properly associated with them with measureable and quantifiable ambiguity in the presence of false detections (i.e., clutter); (3) to produce precise and accurate estimates of the object's motion parameters (e.g., position/velocity/orientation/rates, orbital elements, etc.) amenable to long-term prediction of future motion; (4) to allow detection of changes to these parameters and the identification of trends and patterns in the data suitable for long-term scheduling of future observations; (5) identify and develop computationally tractable methods to enable the development and maintenance of a large catalog of space objects; (6) identify, develop, and implement methods that allow for realistic inference and prediction of space object state uncertainty.

This topic seeks innovative algorithms that maximally exploit the physical interaction of the space environment with space objects to achieve these goals. Priority is given to techniques with sound, rigorous mathematical foundations that treat the problem holistically (i.e., processes that preserve the probability density function (PDF), can handle space object birth/death, clutter, probability of detection, probability of object existence, non-Gaussianity, non-linearity, etc., in a unified framework, e.g., finite set statistics (FISST)). Techniques must have traceability and scalability to the end-application described above.

PHASE I: Evaluate and develop candidate algorithms that will improve the estimation of the satellite location and trends suitable for long-term scheduling of future observations; establish measurement requirements that are compatible with current space object surveillance sensors, select feasible scenarios; evaluate algorithms against measurement requirements vs. estimation improvements.

PHASE II: Apply the results of Phase I to the implementation of algorithms into prototype software; Evaluate algorithm performance against requirements in computer simulations. Apply algorithms to actual sensor data to determine performance.

PHASE III: Military applications include Space Situational Awareness; results should also have application in target detection, tracking, identification, & characterization in other domains.
Commercial applications include flight traffic control & traffic management systems as well as scientific applications.

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KEYWORDS: Satellite, tracking, orbit determination, space situational awareness, identification, characterization, sensing, sensor networks, estimation, fusion, detection, FISST, finite set statistics

AF131-077 TITLE: High Performance Separable Thermal Mechanical Interface for Electronics

TECHNOLOGY AREAS: Electronics, Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of

foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a flight-qualifiable, high performance Separable Thermal Mechanical Interface (STMI) intended for applications requiring high heat flux out of the edges of planar structure.

DESCRIPTION: Digital signal processing remains at the forefront in determining future needs for higher capability spacecraft payloads. Currently, the available level of electrical performance far exceeds the capabilities of the available thermal control techniques. It is the inability of the housing mechanical design to efficiently remove dissipated heat from the active electronics which limits electrical performance. This results in mechanical design aspects becoming the limiting factors defining the maximum level of electronic performance which can be attained. As advances in thermal technology are developed and qualified, the technique for managing waste heat has been identified as a key improvement opportunity. As power levels increase and electronic packaging becomes denser, the thermal interfaces associated with the electronics can only become more critical.

The objective of this topic is to develop a Separable Thermal Mechanical Interface (STMI) that will create a structural thermal interface between the high power density slice-based electronic assemblies and orthogonally oriented heat sinks, which are commonly found in advanced digital processing electronics. The STMI must perform reliably while meeting the stringent thermal performance requirements specified in this document. The technology development of a high performance STMI supports many space platforms by offering new thermal technology to unit design or plug and play small satellites that require the use of slice retainers.

The top level thermal requirement for the STMI is to achieve a specific thermal resistance (in thermal vacuum, 1E-5 Torr max.) less than 0.10 deg C-in/W when averaged over its length. Local variations in specific thermal resistance are to be no more than +/- 25 percent of the average. In addition, the STMI is to be robust and show consistent performance over typical qualification level vibration and thermal cycle exposures, and over multiple insertion and removal cycles. Proposed solutions must have high-reliability and maintenance-free operation for lifetimes exceeding ten years. Finally, the STMI must be compatible with the space environment and conform to space qualification requirements including high vacuum, microgravity, radiation, atomic oxygen, and low outgassing. Proposers are encouraged to team with system integrators and payload providers to ensure applicability of their efforts and to provide a clear technology transition path.

PHASE I: Show through analysis and/or hardware demonstration that a STMI thermal interface on the order of 0.35 C-in/W is attainable. Develop initial concepts and designs for an STMI based on these findings and describe a strategy for making a product available for developers.

PHASE II: Finalize detailed design, manufacture prototype hardware and validate through test the Phase I solutions.

PHASE III: Military/commercial applications: This technology is useful for all spacecraft that utilize a slice-based electronics architecture, which includes both military and commercial satellites.

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KEYWORDS: thermal control, electronics cooling, slice retention, thermal interface

AF131-078 TITLE: Assured Space Sensor Operation in Harsh Electromagnetic/RF Environment

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop an electromagnetically-tailored material for assured sensor operation on SATCOM and/or space-based ISR systems against various electromagnetic environments.

DESCRIPTION: Satellite communications (SATCOM) and space-based Intelligence, Surveillance, and Reconnaissance (ISR) systems in Low-Earth Orbit (LEO) are susceptible to a challenging mixture of electromagnetic (EM) environments, both natural and manmade. These systems receive information, process it, and then retransmit it, all by electronic circuits. Both prompt and enduring radiation effects could corrupt these processes in systems that lack electronic protection (EP). Radiation hardening can protect electronics from many scenarios, but integrating this capability adds significant complexity and cost to the satellite program. So much so that the 2008 "Report of the Commission to Assess the Threat to the United States from EMP Attack" recommends that a cost-effective approach to EP should not be just rad-hardening, but also a balance of mitigation options.

What is needed is an innovative approach to develop these mitigation options for EP on SATCOM and/or space-based ISR systems. A new, expansive field of engineered materials are emerging that offer a means to control the electromagnetic properties of a wave that permeates its structure, through tailoring its reflectivity, transmittivity, and/or absorptivity. Materials that include, but are not limited to, metamaterials, metasurfaces, and carbon nanotubes. These materials open up the possibility to use as an EP technology, and warrants further investigation.

Any material that can interact with EM waves will affect sensor performance. However, as an EP function, the key requirement is that the solution must maintain or improve the performance of the sensor while in the presence of evolving EM environment. It is also required that the solution work symbiotically with the system for quicker integration—for example, as a thin-film surface or as part of the sensor itself. This innovative approach to design will provide the community with an EP technology that can be optimized for mission specific SATCOM/ISR applications without having to consider the complexities of an add-on EP technology. Proof of scalability in the frequency of operation is a must, as this would give rise to a modular toolkit for satellite developers. Low-power active tunability is of interest. Component or system level solutions will be accepted, but a pervasive technology that could apply to numerous components or systems is highly desired. Finally, the solution must prove to be more cost-effective than just rad-hardening.

Primary challenges are the characterization, fabrication and survivability issues of an engineered material. In particular, consider the harsh launch and operating environments that LEO satellite systems undergo. Heavy modeling and simulation for initial investigation of design approaches is highly encouraged.

PHASE I: Identify concepts and preliminary assessment of EP performance, fabrication and space-worthiness. Threshold for protection will be 80dB attenuation at 1 GHz (from Mil-Std-188-12). Simulate performance of solution in high-threat environment, both in isolation and while integrated with a sensor system.

PHASE II: Refine concept based on Phase I. Validate the proposed EP design approach through development, fabrication and test of a prototype article that meets design and technical objectives. Demonstrate maintained or improved sensor performance during simulation of appropriate environment. Provide AFRL with working hardware and samples.

PHASE III:
Military App: Any space-based DoD application that requires a cost-effective, readily-integratable EP solution.
Commercial App: In addition to EP for commercial space systems, unintentional signals--such as co-site interference--could be mitigated in many communications or sensing systems.

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KEYWORDS: ElectronicProtection, ElectronicAttack, EngineeredMaterials, EMP, SensorProtection

AF131-079 TITLE: Ka-band Satellite Phased Array Antenna

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate innovative concepts or component technologies for developing a Ka-band phased array antenna.

DESCRIPTION: Phased array antennas allow the use of many more arbitrarily positioned communication channels (beams) than would be feasible with gimbaled dishes. Using a phased array antenna, beams can be rapidly re-positioned to give time-shared service to a large number of users. For satellite uplink antennas (receivers), improved anti-jamming protection can be achieved by off-axis pointing and jammer nulling. Together, these techniques improve both coverage and capacity for MILSATCOM applications.

Development of a Ka-band phased array satellite antenna with a large number of beams is impeded by both the complexity and high cost of manufacture. There has been substantial work performed over the past decade to support commercial K-band satellite communications phased array antennas. However, there needs to be tailoring for DoD and MILSATCOM use at Ka-band (~30 GHz), particularly for the Wideband Global SATCOM and Advanced EHF systems. These systems can be used by the proposing contractor to establish basic design requirements. Further, recent advances in millimeter-wave electronics and manufacturing technology can contribute to improved design and manufacturing methods for a Ka-band phased array antenna.

The fundamental purpose of this research topic is to develop and / or mature concepts and technologies that will reduce cost, schedule risk, and technical risk for a Ka-band satellite phase array antenna. This phased array antenna could be used to provide 30 GHz aircraft-to-satellite uplink capability. A performance goal would be to provide at least 30 uplink channels (beams) from a single antenna. The specific field-of-study for this research is a millimeter-wave phased array satellite antenna. The specific technology need addressed by this research topic is the design and development of Ka-band phased array satellite antennas.

Innovative designs, manufacturing processes and/or research activities are solicited to support development of a Ka-band phased array satellite antenna. This can include some combination of innovative assembly methods and higher component integration. Successful phase 1 and phase 2 efforts will provide tools and/or mature technologies that reduce cost and / or improve manufacturability of Ka-band phased arrays. Proposers must demonstrate an understanding of satellite phased array antenna manufacturing, systems engineering, and implementation issues. The technical merit of a proposed concept or research activity must be demonstrated with respect to current manufacturing methods and components.

PHASE I: Phase 1 should focus on refining the proposed concept / technology, identifying key technology risks and design uncertainties, and developing mitigation strategies to address those issues in a phase 2 effort.

PHASE II: Phase 2 will improve fidelity of models, reduce key technical risks, and show proof-of-concept through breadboard development, testing, and demonstration.

PHASE III: Military satellite communication systems can use phased array technologies for protected air-to-GEO communication. Technology innovations supporting the military can readily be modified to transition to the commercial fixed satellite service.

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KEYWORDS: Space Communications, phased array antenna, Ka-band, satellite antenna

AF131-080 TITLE: Architecture Model for Decision Makers to Better Understand Complex Systems

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a Core Architecture Model (CAM) for organizations and decision makers to ingest engineering data to aid in understanding complex systems, improving communications, and ultimately making better decisions.

DESCRIPTION: The DoD is currently using a document centric (DoDAF) approach for system architectures. This method limits real-time exchange of changing architecture information and is difficult for decision makers[1] to understand. Furthermore, many modeling tools in DoD are not integrated, resulting in disconnects, re-work, and inconsistencies between program elements. This lack of integration is particularly an issue with system design and architecture tools intended to support system hierarchies, interface analysis, verification and validation, and modeling & simulation activities.

Decision makers require a technical framework that enables sound decision making through the use of trade studies, which are used to analyze trade-offs among system performance, risk, cost and schedule.

Standardizing a tailorable model driven architecture (MDA) [2] using a common language, such as SysML [3], would be favorable. A MDA enables managers and developers to communicate effectively within their programs and between multiple programs. SysML is a widely used model in the DoD that can produce standard DoDAF views.

The Core Architecture Model (CAM) concept is a hierarchical MDA [4] where the CAM is the hub and views such as DoDAF, cost, requirements, risks, etc., as spooks. View elements are connected through the CAM, therefore changes in one view will be updated in other views. Elements in the CAM shall have well defined parameters that the other elements in the CAM or views are concerned with. An element in the CAM can be hierarchical and linked to, for instance M&S tools, to provide more accurate parameter data.

This solicitation seeks the creation of a Core Architecture Model (CAM) for space to facilitate architecture development, design, and trade study analysis within and between complex systems. It must keep track of changes and display affected areas as described by the dashboard proposed below. The CAM could utilize a SysML “engine” where engineering data is ingested. A back-end is required to ingest data in several formats and generate SysML. The engineering data could be system descriptions, requirements, risks, cost or any type of data that is used to develop a complex system.

The second part of this solicitation is a front end dashboard to SysML, providing decision makers with the ability to “turn the knobs” on a variety of engineer parameters and architecture properties of a complex system and observe second and third order affects to system characteristics [5]. For example, a decision maker could alter the number of satellites in a constellation and the dashboard would display the impact(s) to system coverage, availability, resolution, military utility, and other parameters which describe the system’s performance. By “turning the knobs” a decision maker would have immediate insight into the system’s complex interdependencies and could leverage these to perform a trade study to optimize future system. The dashboard shall be a Graphical User Interface that can be used by a non-programmer and must represent system impacts and relationships catered to the decision maker.

This system is not required to be fully automatic. It is expected that system engineers, component engineers, and/or system architects will interact regularly with the system to enable these architecture models and products.

The largest benefit of this system is to couple the decision maker with the engineers, enabling more precise and informed architecture decisions within and between complex systems.

A satellite constellation system example can be provided by ISR.

PHASE I: Phase I will involve developing the concepts for architecture models to understand complex systems. It will also examine the feasibility of the concepts developed in Phase I.

PHASE II: Work in this phase will include a prototype to demonstrate and validate the system. Prove the feasibility of the system. The Phase II program should develop the “turn-key” system ready for use.

PHASE III: The Phase III work would be using the tool for real architecture evaluation of future architectures. Any complex system developed by DoD can use this system. For commercial applications, any complex system developer can use this system.

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KEYWORDS: system architecture, SysML, DoDAF, modeling

AF131-081 TITLE: <u>GPS Awareness Enabling Algorithms for Theater and Space Environment</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Algorithms that can enable operational GPS receivers devoted to position, navigation or timing, (PNT) to also usefully monitor the space environment.

DESCRIPTION: GPS measurements of ionospheric total electron content (TEC) are the primary source of input data supporting the specification and forecasting of ionospheric effects and impacts on DoD radio-based systems, including communication, navigation, surveillance and geolocation. All two-frequency GPS receivers measure TEC in order to remove the position error effect it causes. DoD Space Environment missions most lack TEC where it is most needed: in operational warfighting theaters, and over oceans. Yet DoD vehicles, equipped with two-frequency GPS, are often common in these very areas. If operational GPS receivers in DoD ships, aircraft, and ground vehicles were enabled to measure and report useful TEC observations such capability would dramatically increase space environment awareness in these regions. (Note that 'reporting', that is, output and communication of these TEC measurements, is outside of this topic.) Such enhancement in capability to model and forecast space environment effects would have high payoff for the classes of DoD radio-based systems mentioned above.

New real-time algorithms are required that can operate within GPS PNT receivers and derive reasonably accurate measurements of ionospheric TEC, along with a valid metric of the uncertainty of this TEC data. This new uncertainty metric is vital since this enables modern space environment models to use the TEC data appropriately. Developing a robust and adaptable uncertainty determination process is a key objective of this effort, as this will enable high payoff by means of exploitation of large quantities of low-accuracy data.

To be useful, candidate algorithms must be able to operate with only parameters available within DoD GPS user equipment (UE), and must have low impact on receiver-internal processing loading. In both the measurement and the uncertainty process, algorithms will also need to mitigate recognized GPS measurement issues such as receive antenna multipath and biases from both the receiver system and satellites. For the desired application, however, there are new challenges which include dynamic signal continuity, that is, bridging signal dropouts due to motion, obstructions, etc., and the requirement for occasional complete restart of processes. Algorithm bootstrap startup speed, and robustness against increasing levels of motion, dropouts, etc. will also be challenges. In addition, signal quality monitoring for such issues as noise, interference, and ionosphere scintillation will be important in setting uncertainty levels and determining measurement validity.

PHASE I: Design and develop algorithms that can enable operational GPS receivers to also usefully monitor ionospheric TEC, and deliver results of a feasibility study for algorithm application to GPS receivers in general and GPS User Equipment (UE) in particular.

PHASE II: Demonstrate the capability of candidate TEC and uncertainty - monitoring algorithms in various classes of GPS receivers, in particular GPS UE, by simulation studies and validated field measurements with varying platform dynamics and dropout characteristics. Deliver code and performance metrics for candidate algorithms.

PHASE III: Enable DoD GPS receivers to monitor the ionospheric TEC will forecast theater space environment impact on DoD radio-based systems. New capability to measure TEC and its uncertainty for DoD GPS UE will help the civilian sector by providing improved GPS performance by reducing errors due to TEC.

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KEYWORDS: GPS, ionosphere, ionospheric monitor, total electron content, TEC, space environment, ionospheric impacts, radio-based systems

AF131-082 TITLE: Radiation Hardened Carbon Nanotube-based Nonvolatile Memory

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a high capacity carbon nanotube memory device suitable for use in space memory application.

DESCRIPTION: With conventional silicon based photolithography techniques rapidly approaching the physical limits of feature size reductions, new miniaturization approaches will be necessary to advance density for future generations of radiation hardened satellite memory devices. Recent research in carbon nanotube (CNT) based Resistive RAM has opened possibility of ultra miniaturizing phase change memory feature sizes below what can be achieved through conventional photolithographic fabrication approaches. For example, when CNT is transferred to RRAM (Resistive Random Access Memory) it was possible to create a 6- by 6-nm (nanometer) memory cell. Evaluation of CNT (Carbon Nanotube) based memory suggests that it is inherently radiation hard making it an ideal candidate for operation in space. Before radiation hardened nanotube memory is viable for insertion into space, a fabrication process must be developed and proven that is both reliable, affordable, and of a density that makes it attractive for insertion into future space programs. Obstacles include achieving a reliable and high yield production process, including precision control of cross-wire patterns, spacing and tube growth. The purpose of this topic is to support the development of a radiation hardened CNT or graphene memory device suitable for insertion into geosynchronous satellite applications. Goals include density >16M bits per device, radiation tolerance >1Mrads(Si) total dose, access time <10ns (read), immunity from Single Event (SEE) radiation effects and extended operating temperature range (–55 to +125 degrees Centigrade).

PHASE I: Design a CNT/graphene based memory and validate the design through modeling and simulation. Perform test and evaluation of the technology proposed through basic materials characterization and prototyping.

PHASE II: Fabricate nanotube and/or graphene memory device at a density that can verify the technology (less than 16Mb is acceptable) based on phase I design and characterize for access time, mean-time-to failure, operating voltage, radiation characteristics, and operating temperature range.

PHASE III: High capacity carbon nanotube (or graphene) memory device will be suitable for use in Military space memory applications. There will be significant uses also for commercial satellite applications.

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KEYWORDS: Carbon nanotube, flash memory, phase change memory, nonvolatile memory, nanoscale, resistive random access memory, graphene

AF131-083 TITLE: Low Temperature Solid State Refrigeration

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop a cryogenic, solid state, no-moving-parts thermal control system for use aboard spacecraft.

DESCRIPTION: This solicitation seeks to develop a completely solid state, no-moving-parts refrigeration system that can be applied to cooling a focal plane array or other electronics in a space environment. The space environment for these purposes includes a heat reject temperature of nominally 300K and exposure to a vacuum. This entails cooling a flat surface roughly 25 square cm to less than 123K. The heat load for demonstration should be greater than 0.5W, though future real-world demands will be higher. Corresponding system specific power and specific mass should be on the order of 100 W/W and 1 kg/W.

Current cryogenic refrigeration (i.e. cooling to temperatures less than 123K) technologies used to cool low temperature space-based EO/IR sensors use refrigeration cycles that depend on the expansion of a refrigerant gas, e.g. Brayton and Stirling type coolers. Though relatively efficient, these coolers rely on moving parts (compressors and expanders) which both create vibrations that can induce jitter into a telescope and reduce the expected lifespan of the system due to wear and fatigue. Additionally, the existing coolers require large masses for heat transfer components (e.g. recuperators and regenerators), compressors, and to contain high pressure gases.

Solid state cooling, such as is done by thermoelectric devices and laser cooling, can overcome many of the mechanical coolers disadvantages by making a compact device that uses only electricity to produce a temperature gradient and transfer heat. While prior work has made substantial progress in optical cooling, only temperatures down to 155K have been accomplished in experimental settings with no method of heat rejection. Similarly, thermoelectric coolers require several stages to accomplish a large temperature gradient and, due to the number of stages, two-dimensional heat spreading becomes an issue because of the decreasing area – a result of each subsequent stage having to compensate for the inefficiency of the previous stage. Both thermoelectric and optical cooling can theoretically cool well into the cryogenic regime, with modeling putting thermoelectric devices around 10K and optical cooling as low as 80K. The primary issue with these methods is the materials' performance.

Though current focus has been on Peltier and optical cooling, other novel methods are encouraged, e.g. applying effects such as magnetocaloric, electrocaloric, thermotunneling, Ettingshausen, or a combination hybrid system constructed in such a way that there are no moving parts.

PHASE I: Phase I SBIR efforts should concentrate on the development of the fundamental concepts for a low size, weight, and power solid state cryogenic refrigerator that is applicable to spacecraft. Determine expected performance through analysis and modeling efforts. Identify technical risks and develop a risk mitigation plan for Phase 2.

PHASE II: Phase II SBIR efforts should take the innovation of Phase I and design/develop/construct a breadboard device to demonstrate the innovation. This device may not be optimized to flight levels but should demonstrate the potential of the prototype device to meet actual operational specifications.

PHASE III:
Military App: cryogenic sensing systems relate to infrared sensing, cryogen management, electronics cooling, and superconductivity.
Commercial App: Medical applications such MRI machine magnet cooling, cooling of IR cameras, gas liquefaction and use in telecommunications cooling.

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KEYWORDS: cryocooler, cryogenics, solid state, infrared, sensors

AF131-092 TITLE: On-Board Autonomy for Decreased Satellite Response Time

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Research and develop architectures for autonomous flight software to support on-board event detection, planning, and task execution in order to enhance satellite responsiveness.

DESCRIPTION: Today's Air Force satellites are not equipped to respond to real-time events whether those are due to component failure, environmental, or man-made. The state of the art (SOTA) in existence today largely requires ground operations to identify, isolate, and mitigate most threats or to respond to opportunistic scenarios. Without embedded flight autonomy the time to identify and respond to events can be on the order of days. In addition, some surveillance missions are less than effective with increased timelines resulting in the inability of Warfighters to respond to observations. In support of future Space Superiority missions, monitoring and command and control functionality which traditionally has been hosted on the ground needs to be migrated on-board the satellite. Investments have been made in developing specialized sensors to detect specific events. What is needed is to improve the SOA in existence today and to create a more robust on-board capability that will detect and isolate non-deterministic events, plan resulting actions, and then execute activities. Events can be determined from either on-board sensors or as a result of on-board processing of sensor data. This requirement leads to several challenges. Detecting and correctly identifying events via telemetry, on-board sensors and/or environmental conditions is made difficult due to the difficulty in characterizing these events. Once identified correct courses of action must be determined. To correctly perform this function embedded knowledge of satellite state, operating constraints and mission objectives must be very accurately maintained. This on-board knowledge base is necessary to robustly plan resulting actions. Once these activities are determined they must then be properly executed in the correct sequence and at the appropriate times. This topic seeks to develop and demonstrate technologies for embedded satellite autonomy. Example technologies to achieve desired objectives would include but not be limited to model based and constraint based detection and planning systems.

PHASE I: For selected scenarios develop and demonstrate on-board software technologies to perform autonomous flight operations. To the extent possible the research should leverage off of previous research in FDIR, autonomous planning, and task execution. Particular emphasis should be placed on scalability and accuracy.

PHASE II: Build on the architecture developed in Phase I and incorporate higher fidelity components at all levels. This phase will target a set of realistic scenarios and operating constraints. Phase II will culminate in a high fidelity prototype demonstration of the system that clearly shows the utility to Space Superiority missions.

PHASE III: This topic is addressing Space Superiority Space missions. The associated technologies would be applicable to NASA missions particularly those that are in deep space where bandwidth is a limitation.

REFERENCES:
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KEYWORDS: Space Superiority, Space Situational Awareness, Autonomous Flight Software, Satellite Autonomy

AF131-093 TITLE: Small Cryogenic Refrigerator for Single FPA Dewars

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a refrigerator suitable for a microsat or 3U cubesat with an individual FPA dewar and IR sensor assembly.

DESCRIPTION: Miniaturized satellites, such as cubesats and microsats, are becoming more popular for smaller missions due to their typically reduced cost and development time through use of commercially available components. However, instruments such as infrared focal plane arrays require cooling to cryogenic temperatures – a feat that has historically demanded high size, weight, and power (SWaP). Current space-ready cryogenic refrigerators don’t meet the SWaP requirements of such miniature satellites.

This solicitation seeks an innovative refrigerator (cryocooler with control electronics) that has to fit in a 3U cubesat (see Cubesat Design Spec. v12 at www.cubesat.org/images/developers/cds_rev12.pdf) or microsat supporting single Focal Plane Array (FPA) dewars within Electro-Optical/Infrared (EO/IR) sensors. There are no restrictions on size once in orbit. The refrigerator has to fit within the total spacecraft mass and power budget of 4 kg and 50 W respectively. The refrigerator will meet the requirements by the IR sensor and the Focal Plane Array.

The technology will be capable of supporting a 10-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and a five year mission in Low Earth Orbit (LEO) after five years of ground storage. The deliverables for this effort should use parts selected for 150 krad total dose (LEO or GEO); however, higher radiation hardness levels (up to 1 Mrad total dose for MEO) should be alternative parts of the design.

Two space-flight ready refrigerators will be delivered with a one-year (as a minimum) design life in LEO orbit. The Phase II effort should use low-cost, commercially available cryocoolers while developing rad-hard control electronics. The testing of this prototype system should be indicative of how a long-life cryocooler would be controlled by the electronics if a 5-10 year mission were to be supported.

Mission parameters defining the performance envelope are:
Cooling temperature: 100 K
Cooling load: 1 W
Rejection temperature: 275-325 K
Duty cycle: 100%, restarts for radiation upsets allowed.
EMI/EMC: no phase 1 criteria; will be developed in phase 2.

The radiation environment for LEO, GEO, and MEO orbits must be assessed as part of Phase I and then parts selection processes identified in Phase II to support 1- to 10-year mission life durations at those orbits.

The small business doing this work must be certified for SECRET collateral work and no foreign nationals can work on this project.

A successful Phase I will initiate partnerships with commercial payload vendors who in Phase II will provide specific needs to ensure successful EOIR payload integration. It is suggested that such plausible commercial partners be identified in Phase I proposals. The Phase III will directly involve such partnerships to develop the demonstration payload.

There is no requirement for use of any government materials, equipment, data, or facilities.

PHASE I: The Phase I work should include fabrication of a representative electronics breadboard to prove performance feasibility and analysis of volume and power feasibility.

PHASE II: The Phase II should develop the process and procedures to fabricate, test and deliver multiple space flight ready individual refrigerators. Verification of these procedures through launch and duration tests in a relevant space environment is required. The Phase II should demonstrate applicability to either military or commercial use in a Phase III.

PHASE III: The Phase III work will launch this as Space technology demonstration. The microsat or cubesat can be used for security applications and other DOD payloads. The constellation can be used for environmental monitoring and experiments.

REFERENCES:
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KEYWORDS: cryocooler, cryogenic, satellite refrigeration

AF131-094 TITLE: Characterizing the Impact of Ionospheric Wave Structures on Coordinate Registration

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: To enable characterization of the impact of ionospheric wave structures on coordinate-registration for over the horizon radar and other applications.

DESCRIPTION: Due to its long range ability, wide area of coverage per installation, and low cost per square km of coverage, over the horizon radar (OTHR) has the potential to fill surveillance gaps in North American defense and security. In particular the vast air/oceanic expanse represented by the Atlantic/Pacific/Caribbean basins require affordable surveillance options.

At the operational heart of an OTHR lies the transmission of a beam of radio waves into the sky where it reflects off the ionosphere and out to locations beyond the line-of-site horizon (2000 - 5000 km). Once there it can scatter off targets of interest and then takes another sky route to one or more detection sites. Knowledge of the ionosphere is critical to successful operation of any OTHR device. The optimal frequency for transmission is set by ionospheric conditions, and such knowledge is also critical to coordinate registration (CR). CR is the process by which the information received is converted into an estimate of the location of a target. In general, knowledge of the ionosphere, along with a measure of the time of flight of the radar beam, allows determination of the direction and distance to the target.

Current approaches to CR range from a 'mirror in the sky' paradigm, where the reflection height is assumed constant and the ionosphere acts like a horizontal mirror at that altitude, to explicit ray tracing through a model ionosphere which may be adjusted with observational data. The more advanced approach allows for inclusion of such features as horizontal gradients and changing reflection heights as a function of frequency, azimuth, and zenith. Obviously such an improved approach requires improved knowledge of the ionosphere. One relatively new feature of our understanding of the ionosphere is the ubiquitous presence of migrating wave structures, sometimes referred to as traveling ionospheric disturbances (TIDs). These are typically understood as gravity waves (similar to ocean waves) and have been observed at a variety of wavelengths and amplitudes. Such structures are not resolved by the ionospheric modeling described above and it appears that the error ellipse associated with CR is often set by such waves in the ionosphere.

Initially the potential impact of TIDs in various OTHR relevant settings must be understood. This should be based on a survey of state of the art TID observations and generation mechanisms and will require state of the art modeling to understand how and where TIDs are impacting CR. The simulations must be detailed enough to distinguish between the impacts of different types of TIDs on different types of targets. Vertical as well as horizontal propagation should be investigated.

Once the magnitude of the impact in various situations is understood, measurements capable of resolving local TID structures will be required to be incorporated into the simulations and compared to actual operational systems. The fielded system should represent an innovative solution to performing routine measurements of wave structures in the bottom side ionosphere. It would be very useful for the system to be scalable in terms of area of coverage, thus low cost per area is also desirable. The final integrated hardware/software system should be able to inform the cost and benefit of fielding TID resolving hardware as part of arbitrary systems requiring CR.

PHASE I: Produce a tool capable of simulating 3D HF propagation through a flexible ionospheric environment and providing output as used/produced by an OTHR system, e.g. vertical and oblique incidence ionograms, Doppler space, group path and bearing to a target. Simulate the full system, e.g. include the ability to invert specified measurements to retrieve TID characteristics in the simulated ionosphere.

PHASE II: Field and operate a system capable of resolving TID structures at the range of scales relevant to CR. Couple the measurements from that system to the simulator produced in Phase I through an assimilative ionospheric model also capable of ingesting data from other sources. Validate the model with ground truth, e.g. predict sensitivity of retrieved fields to sampling rate or frequency stability. Characterize the effects on simulated OTHR retrievals. Compare to data from an operational OTHR system.

PHASE III: Provide a tool to OTHR and CR users capable of including the effects of TIDs in their operations. Improved specification of HF radio circuit paths provides insight into HF communications systems design/performance, and signal fade/loss margins. Move R&D level understanding of TIDs forward.

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KEYWORDS: over the horizon radar, OTHR, traveling ionospheric disturbance, coordinate registration, ray tracing, ionospheric modeling, data assimilation

AF131-095 TITLE: Development of Space Platform Local Area Sensors and Data Processing & Fusion Algorithms for Threat Detection, Indication, Tracking, and Characterization

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop low size, weight, and power (SWaP), low-integration-risk sensors, sensor suites, sensor algorithms, and/or sensor data manager to support threat detection, tracking, characterization, notification, and anomaly tip-off and resolution.

DESCRIPTION: The DoD is pursuing technologies that afford space system owners/operators the ability to detect, track, and characterize potential threats and hazards to space platforms. This requires development of new sensors and/or the modification of existing sensors to actively or passively understand phenomena in the spacecraft's local area. ('Local area' includes the nearby space surrounding the spacecraft as well as the physical and digital space on-board the spacecraft). It will also require the development of tools and methods for local area sensor (LAS) data management, processing, and fusion. Ideally, a LAS suite would be comprised of various sensor types collecting data pertaining to potential threats along with a sensor manager to process sensor data and produce information on the potential threat that is meaningful to the system owner/operator.

The Space Vehicles Directorate is investigating several sensing categories to meet these goals.

1. Object sensing: Senses presence and external characteristics of nearby objects.

2. Emission sensing: Sense emissions occurring in the local area allowing the user to infer the presence and/or characteristics of nearby objects (emitted electromagnetic radiation or effluents).

3. Effect sensing: Sense the effect caused by the nearby object on the system and/or its operations that will not necessarily be detected by standard health and status sensors (localized temperature increase, vibration sensors, etc.).

Sensors considered for development may include new or novel designs but it is typically considered more desirable to investigate the possibility of modifying sensors currently used for other applications. An example of this type of modification is the use of bolometers for detection of approaching objects.

Individual sensor proposals must indicate whether the goal of the effort is to research and demonstrate a specific sensing technology or to develop a complete sensor package with filters, data interfaces, and associated algorithms.

The proposal must also describe the intended method for sensing the targeted object, emission, or effect. This may include rejection of contamination by out-of-band spectral, abd off-axis solar, irradiance through solar occultation, baffling, smart optical design, specialized filters and coatings, or any other means that meet the requirement. It is also important to indicate expected sensor requirements (power, location, etc.) and conditions under which the sensor will not be able to perform its intended function. Of secondary interest is the characterization of sensor degradation over an expected operating lifetime of 15 years.

Sensor suite proposals must describe the overall sensing capabilities that the various sensors would provide. Special consideration should be given to understanding the data output of the sensor suite in order to recommend future work developing a sensor data manager. Some thought should also be given to how processed data will be transmitted to the ground and what automated actions the sensor suite might enable. The sensor suite proposal must include an assessment of SWaP requirements, data processing needs, and other constraints (ability to process and correlate data from multiple sensors simultaneously, location restrictions, sensing limits, cooling requirements, etc.)

A LAS package is intended to provide additional information to the owner/operator but it is not the primary payload. It must be low SWaP, present minimal integration risk, and must not interfere with on-orbit operations of the payload or the supporting platform (i.e. interference with other sensors, interruption/disturbance of command and data handling, etc., should be avoided). The prior state-of-the-art has not led to acceptable conditions for the hosting of LAS by spacecraft program offices, arising from a combination of non-negligible SWaP or risk of impacting primary payload performance.

Commercial spacecraft (e.g. communication and media broadcast) may benefit from this technology to help aid in on-orbit anomaly resolution. Diagnostic information helping to distinguish between natural causes and manufacturer defects as the source of a problem on orbit might help facilitate recovery. The substantial cost of insuring such commercial spacecraft strongly suggests that the spacecraft insurance industry would be interested in the results of this SBIR.

PHASE I: This will depend on exactly what research is proposed, but at the end of Phase I, a well-researched concept and preliminary design is expected.

PHASE II: This will depend on exactly what research is proposed, but at the end of Phase II, we will expect a final design (including modeling) and a breadboard built. Phase II may include laboratory testing of the breadboard.

PHASE III: This will depend on exactly what research is proposed, but at the end of Phase III, a demonstrated prototype is expected.

REFERENCES:
1. Hilland, D. H., "Satellite threat warning and attack reporting," Aerospace Conference, 1998 IEEE, Volume 2, p 207-217, 21-28 Mar 1998.

2. Andreas, N. S., "Space-Based Infrared System (SBIRS) system of systems," Aerospace Conference, 1997 Proceedings IEEE, Volume 4, p 429-438, 1-8 Feb 1997.

3. Wilson, Tom, "Threats to United States Space Capabilities," Commission to Assess United States National Security Space Management and Organization, 2001 (Global Security.org website).

KEYWORDS: local area sensors, threat warning sensors, space sensors, satellites

AF131-098 TITLE: Short Wave Infrared (SWIR) Test Capabilities for Imaging Sensors

TECHNOLOGY AREAS: Sensors, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of

foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a compact wide field of view, near and shortwave infrared band image projector to provide real time detector stimulation with high dynamic range target, stellar, and background.

DESCRIPTION: Visible-Near Infrared and Short Wave Infrared ((VNIR-SWIR) sensors (0.4 to 0.8 and 0.8 - 3.0 microns) are becoming increasing prevalent for military applications; however, the laboratory capability to stimulate prototype or imaging SWIR sensors is urgently needed to enable development of the sensor capability. The ability to perform in-band replication of complex target and background phenomenology is essential for development of weapon system ranging from Air Force ground targeting lasers, advance missile guidance, unmanned air vehicles, and satellite navigation systems.

Research and development for novel large format infrared detector stimulation and scene projection are at the highest Air Force priorities for next generation targeting sensor and seeker development. Innovation is needed to determine an optimum way to stimulate prototype novel broad-band, high resolution VNIR- SWIR detectors. The research challenge is to represent low noise level backgrounds while simultaneously accurately representing high power targeting laser reflections, and transient emissions from a target or natural background. For longer wavelength phenomenology, where lower temperature emissive sources are predominant, resistive array projection technologies exist that provide continuous dynamic control and continuous output. The same cannot be said for SWIR bands, which are a combination of reflective and emissive domains. Limited capabilities have been attempted based on modification of visible projectors, these do not have the dynamic range and ability to provide blur free wide-spectral band high contrast stimulation for short exposure range gated imagers.

The research challenge is precision representation of sky and backgrounds emissive and reflective signatures with high temperature target/clutter emissive effects. Detectors are now sensitive enough that spectrally selective airglow and halide light scatter are significant environmental sources at night. "Night Glow" is a naturally occurring light source that is emitted from the night sky created by the interaction of the earth's atmosphere with the solar winds. This naturally occurring but relatively unknown phenomenon results in a considerable amount of light or "night glow" that comes from the entire night sky. However, the light is emitted in the short wave infrared (SWIR) band with wavelengths of 1200 to 1800nm. Ability to simulate all common laser sources in the band for both atmospheric scatter and target specular/diffuse reflection while maintaining good low noise scene background is a technical challenge. New high-power SWIR Vertical-Cavity Surface-Emitting laser (VCSEL) sources are now available for target illumination and SWIR laser array technology has advanced considerably during the last decade providing synthetic low noise target illumination.

Innovative solutions are needed that provide flexibility for detector development, integration and test. These include continuous precise analog control of pixel output, adaptive source intensity for optimal grayscale range, potential integration into multi-waveband test systems, and simulation of active illumination sources. Other technologies have also shown promise, e.g., light emitting diode arrays and liquid crystal arrays. Solutions are desired that can achieve formats greater than 1024x1024 leading to 2K by 2K and can adaptively apply their dynamic range to resolve both night-time starlit scenarios and daytime scenarios with solar illumination. Solutions should be compatible with lightweight, flight table compatible SWIR projector configurations. Fields of view may range from a few degrees to wide field of view applications with 60 degrees or larger field of regard. Frame rates from a few hertz to 2kHz are eventually needed.

The potential for integration of Long Wave IR, Mid Wave IR and semi-active laser designator/rangefinder/pointer targets into the optical path should be taken into consideration. Laser scatter and reflections at red, green, NIR pointer, 1.06 and 1.55 micrometer are typical lasers that need to be represented. Potential applications include a range of possible field-of-views, from a few degrees for a terminal homing sensor to extreme wide field-of-view multi-aperture sensors intended for optical flow navigation. The target test environment will require non-uniformity correction and absolute calibration at all output levels. Address calibration, non-uniformity correction, wide field of view, and scene generation aspects for the projector system.

PHASE I: Develop a SWIR image projector concept for weapon and staring stellar inertial sensor stimulation reproducing sub-nanowatts to millliwatts per pixel over the 400nm to 3000nm range. Analyze the concept for high speed image sensor stimulation to provide spectrally accurate output to support camouflage, foliage, and target detection.

PHASE II: Develop and demonstrate component technologies, interfaces, and software necessary to demonstrate a prototype projection system. Demonstrate calibration, non-uniformity correction and stability before and after representative test cases involving adaptive source intensity.

PHASE III: Develop and transition full up SWIR sensor-seeker and stellar inertial sensor calibration and test systems for use in government and defense industry hardware-in-the-loop applications.

REFERENCES:
1. J. Geske, C. Wang, et al., “High power VCSELs for miniature optical sensors,” Proc. SPIE 7615, 76150E (2010), DOI:10.1117/12.847184.

2. J. R. Lippert, H. Wei, et al., “Record breaking high-apparent temperature capability of LCoS-based infrared scene projectors,” Proc. SPIE 7663, 76630S (2010), DOI:10.1117/12.850184.

3. R. L. Murrer, R. A. Thompson, and C. F. Coker, Developments at the Kinetic Kill Vehicle Hardware-in-the-Loop Simulator (KHILS) facility Proc. SPIE 3697, 31 (1999), DOI:10.1117/12.352921.

4. D. C. Dayton, J. Gonglewski, et.al., ”SWIR Sky-Glow Cloud Correlation with NIR and Visible Clouds-An Urban and Rural Comparison”, Optics in Atmospheric Propagation and Adaptive Systems XII; September 3, 2009; Berlin, Germany. 377AWB-2009-0983; July 27, 2009. AFRL-RD-PS-TP-2010-1011.

5. G. A. Tidhar, et.al.,”The role of SWIR building blocks in Hostile Fire Indication and Missile Warning Systems”, Infrared Technology and Applications XXXVI, edited by Bjørn F. Andresen, Gabor F. Fulop, Paul R. Norton, Proc. of SPIE Vol. 7660, 76600F 2010 SPIE.

KEYWORDS: SWIR, NWIR, laser guided bomb, Star Tracker, Projector, HWIL testing, camouflage, sensor, guidance, stellar navigation

AF131-099 TITLE: Multi-aperture Sensors for High Speed Weapon Applications

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop concepts that take advantage of multi-aperture sensor technology to actively mitigate thermal loading associated with Mach 5+ flight. Innovative sensor solutions are desired for high-speed guidance, navigation, and situational awareness.

DESCRIPTION: Multi-aperture sensors based on biological principles offer numerous advantages: low weight and complexity, very wide field of view, low optical distortion, large depth of field, and minimal solar exclusion. Recently, multi-aperture designs have been developed in both the visible and infrared to demonstrate these advantages for general purpose wide-field-of-view sensing. Multi-aperture sensors might have distinct advantages for thermally stressing high-speed flight due to the decreased individual aperture size and multi-use potential for the structure connecting the apertures. The smaller individual apertures could minimize thermal gradients and the structure connecting the apertures could provide a means for cooling through some combination of conduction, internal convection, and transpiration cooling. Cooling is critical to these applications due to the increased noise and associated loss of sensitivity resulting from elevated backgrounds. This degradation is compounded by increased optical component emissivity in some bands as the temperature rises. Combinations of active cooling and algorithmic solutions may be possible that will enhance sensitivity and reduce background and spatial noise in the high enthalpy environments associated with hypersonic flight. Innovative concepts are desired that take advantage of the design features of multi-aperture technologies to demonstrate operational capability in regimes that would typically limit exposure to very short duration or require flowfield coolant injection with associated optical degradation. The confluence of a number of disciplines is likely required to prove concept feasibility: optical modeling, structural response, thermal response, radiance transport, flowfield modeling and boundary layer energy transfer.

PHASE I:  Investigate concepts for application of multi-aperture sensors to high-speed flight. Perform design tradeoffs using modeling and simulation techniques. Down-select and perform detailed prototype design for future concept demonstration and design an experimental process for design validation.

PHASE II:  Implement, integrate and demonstrate hardware and software solution(s) developed in Phase I. Execute an experimental program using the prototype hardware to demonstrate performance capabilities and limitations. Document the design concept and prototype experimental results. Design and document a final concept based on lessons learned during the Phase II activity.

PHASE III:  Transition technology to military and space applications, addressing manufacturing and producability issues. Establish ties to major DoD contractors for development and demonstration of designs in relevant high-speed environments.

REFERENCES:
1. Patent US 7,587,109 B1, “Hybrid Fiber Coupled Artificial Compound Eye,” Spectral Imaging Laboratory, Francis Mark Reininger, Sep. 8, 2009.

2. www.spilab.com.

3. Harris, D.C., Materials for Infrared Windows and Domes – Properties and Performance, SPIE Press, 1999, ISBN 0-8194-3482-5.

KEYWORDS: Infrared Imaging, Multi-Aperture, Wide Field-of-View, Hypersonic, Compound Eye, Aero Thermal Response, Cooling, Guidance Navigation and Control

AF131-101 TITLE: Wide-Field-of-View (WFOV) Multiwaveband Multimode Seeker Technology

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE:  Develop wide-field-of-view multimode (non-gimbal) seeker concept with one mode being multi-waveband passive imaging IR and the second mode being semi-active laser (SAL).  Sensor provides man-in-the-loop guidance with enhanced end-game engagement.

DESCRIPTION:  Current and future military operations, including difficult environments such as urban terrain, and the desire for controlled damage effects, require improved levels of situational awareness, responsiveness and weapon precision.  Small (<50lb net weight) and agile munitions require precision guidance capability to maneuver in obstruction-rich and highly cluttered urban terrain for engagement of soft fixed and mobile targets.  The loss/degradation of GPS and communications encountered in urban environments and intermittent line-of-sight to the target add additional guidance system challenges. Precision guidance is tightly coupled to lethality in that small weapons must achieve exceedingly small circular area probable (CEP) to accommodate small warheads. Hence the weapon may need to employ complex engagement geometries such as fly-over and shoot-down, or entering windows and small openings. The tactical nature of these small weapons makes man-in-the-loop operation desirable, to permit in-flight target designation updates using a human-operated laser designator while (or in lieu of, depending on the circumstances) the weapon autonomously guides to its target using the passive mode seeker sensor information. A multiwaveband seeker will enhance the probability of correctly identifying and tracking targets and discriminating from non-targets. In addition to providing high performance, the guidance subsystem must be small. The payload available on small weapons creates a challenging trade space for the size, weight, and power (SWaP) of each weapon subsystem. Solution concepts, including the seeker, the avionics processor, power and navigation system, should target the smallest SWaP possible but should not exceed 6in diameter, 5lb, and 50W power consumption. Seekers are of interest at two scales: less than 5 in diam, and less than 2.5 inch diameter.

PHASE I: Identify innovative technologies for development and testing of low SWAP, WFOV multimode, multispectral seekers that will lead to meeting the described goals, with a SAL mode integral to the seeker design. Develop a conceptual design and analyze the performance and limitations of the technologies.

PHASE II: Produce a system design and prototype of a seeker capable of both (1) autonomous closed loop guidance and flying autonomously, or (2) being controlled by a human-in-the-loop, designating a target.

PHASE III: Commercial Application: Surveillance activities in law enforcement, search and rescue, border control, homeland security. Machine vision for manufacturing, robotics, or vehicle situational awareness/safety systems.

REFERENCES:
1. US Patent 7,587,109 B1 (8 Sept 2009) Hybrid Fiber Coupled Artificial Compound Eye.

2. W.Shi, M. E. Couture, "Thermal and ghost reflection modeling for a 180 degree field of view long wave infrared lens," Proceedings of SPIE vol 4198 (2001).

KEYWORDS: semiactive laser guidance, multispectral, sensor fusion, human-in-the-loop, autonomous guidance and control, wide field-of-view, laser designated

AF131-102 TITLE: <u>Communication-Embedded RF Seeker</u>

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Research and develop multi-function radar seeker technology for application to air-delivered weapons.

DESCRIPTION: Software-configurable radar systems have allowed radar engineers the flexibility to carry out many modes using a single, flexible hardware configuration. The Weapon Seeker Sciences Branch of the Air Force Research Laboratory Munitions Directorate (AFRL/RWWS) has capitalized on such concept and small, low-cost multi-mode radar seekers (i.e.: radar seekers that implement a combination of modes such as Synthetic Aperture Radar (SAR), Doppler Beam Sharpening (DBS), Ground Moving Target Indicator, High Range Resolution, acquisition, single and multi target tracking) have become viable solutions for weapon applications. In recent years, the same software defined concept has evolved to allow for practical implementations of multi-functional RF systems. Functions such as communications, electronic warfare (EW), navigation, and collision avoidance can be integrated to complement the main radar functions. High-speed communication is of particular interest for its use in weapon’s In-Flight Targeting Updates (IFTUs), Battle Damage Assessment (BDA), and potential future use in cooperative networks.

It is the intent of this solicitation to develop a concept and architecture for a multi-function radar seeker capable of embedded communications and develop an integrated waveform generation and receiver subsystem capable of meeting the requirements for the concept. As a minimum, the subsystem must have the necessary computational capability to control and process the waveforms necessary for a high performance, multi-mode pulsed-doppler radar seeker operating in the SAR mode with 6” resolution and having three down-converted receive monopulse channels. The subsystem should also support diverse high data rate waveforms compatible with commercial wireless applications for operation as a standalone radio and in the form of inter-pulse modulation within a set of radar pulses. It is expected the subsystem to follow a similar software architecture as a software defined radio and perform within the limited power and size limitations of a radar seeker (e.g. for radar SWAP: Size < 100in3, Weight < 6lbs, Prime power < 100W).

PHASE I: The phase I effort should refine the architecture for a multi-function radar seeker capable of embedded communications, define the hardware and software requirements for the integrated waveform generation and receiver subsystem and perform a preliminary design.

PHASE II: The phase II effort should further develop the design and demonstrate functionality of a brassboard prototype of the integrated waveform generation and receiver subsystem.

PHASE III: The developed brassboard prototype should be integrated and demonstrated as a full-up RF system.

REFERENCES:

1. J. Proakis, M. Salehi, Digital Communications. New York: McGraw-Hill, 2008.

2. N. Levanon, E. Mozeson, Radar Signals. John Wiley & Sons, 2004

3. M. Skolnik, Introduction to Radar Systems, 3rd ed., McGraw-Hill, 2001.

4. G. V. Trunk et al., “The advanced multifunction RF concept,” IEEE Trans Microwave Theory Tech., vol. 53, no. 3, pt. 2, pp. 1009–1020, Mar. 2005.

5. M. Roberton and E. R. Brown, “Integrated radar and communication based on chirped spread-spectrum techniques,” in IEEE MTT-S International, Microwave Symposium Digest, Jun. 2003, vol. 1, pp. 611–614.


KEYWORDS: Multi-function radar, seekers, data links, radar waveforms, digital waveforms

AF131-103 TITLE: Kilogram-Scale Production of Air-Stable Nano-Scale Energetic Core-Shell Clusters

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop scalable processes and technologies for the production of air-stable 5-25 nm scale energetic core-shell clusters comprised of metallic components that undergo inter-metallic or thermite-like reactions.

DESCRIPTION: The Air Force is interested in material processing technologies for the production or fabrication of nano-scale core-shell cluster materials with particle diameters < 25 nm. There are several possible approaches (including, but not limited to): (i) aerosol condensation methods and (ii) colloidal wet-chemistry based assembly techniques.

(i) Aerosol processes for the formation of core-shell nano-clusters involve one of the following methods: the formation of liquid droplets by directing a jet of a source liquid onto a surface or into a stream of gas, by applying high pressures to source liquid and forcing it through a small orifice, or by dropping a source liquid onto a very fast rotating surface. After the formation of the small droplet of, the "core" material, core-shell composite structures could be created through the pyrolysis of the liquid aerosol in the presence of the "shell" material.[1]

(ii) Colloidal mechanisms for the formation of core-shell nano-clusters may include the breaking down of larger "bulk" source materials to nano-scale through comminution or by building up atoms and molecules into clusters through aggregate condensation. After formation, shell structures can be formed on spherical colloids by means of controlled adsorption of another species through precipitation, graft polymerization, or through sol-gel techniques.[2]

PHASE I: The contractor will develop a scalable process for the creation of air-stable 5-25 nm scale core-shell clusters through both modeling and small scale-testing. Initial tests must demonstrate proof-of-concept (10 grams of material produced, at rates of at least 1 gram per hour) and scalability of production rates. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and validate a large scale energetic nano-cluster formation process. The nano-cluster formation process shall produce air-stable 5-25 nm scale energetic core-shell clusters at rates of at least 100 grams per hour. Deliverables are a prototype of the process, a demonstration, experimental data of the production and cluster formation process, a model incorporating the production and cluster formation data, and an analysis of the resulting material.

PHASE III:
Military Application: Air-stable 5-25 nm scale energetic core-shell cluster based material suitable for use in munitions with production rates of at least 10 kg per hour.
Commercial Application: Improvement of energy output of jet fuels.

REFERENCES:
1. Prakash, A., A.V. McCormick, and M.R. Zachariah, Tuning the Reactivity of Energetic by Creation of a Core-Shell. Nano Letters, 2005. 5(7): p. 1357-1360.

2. Caruso, F., Colloids and Colloid Assemblies: Synthesis, Modification, Organization and Utilization of Colloid Particles2004: John Wiley & Sons. 621.

KEYWORDS: nanoenergetics, clusters, core-shell, energetic materials, scalable, colloids, aerosols

AF131-104 TITLE: <u>Fuel-Air Explosive Technologies from Dual-Use Materials</u>

TECHNOLOGY AREAS: Materials/Processes, Electronics, Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop enabling technologies for a single event, fuel-air explosive (FAE) based on the liquid fuel, JP-10, used in propulsion systems.

DESCRIPTION: There is a need for smaller weapons systems that will retain the lethal performance of the larger systems they will replace. One approach to miniaturizing ordnance is to use dual-use or multifunctional materials. Under this topic, residual JP-10 from the munition's propulsion system would be used as a fuel-air explosive (FAE) to augment the blast performance of the standard warhead. These enhanced blast ordnance would be used in delivery vehicles that already carry JP-10 – either low-speed UAV-based platforms powered by turbine engines or high speed cruise missiles powered by ramjet/scramjet engines. These propulsion systems have residual fuel in their fuel tanks as a safety margin, and fuel amounts can be significant if the actual cruise range is below the maximum cruise range.

There are multiple technical challenges that must be addressed: (a) creating an ignitable vapor/aerosol cloud from a low vapor pressure fuel; (b) dispersing the cloud at the proper fuel-air concentrations (within the upper and lower flammability limits); (c) developing a single event ignition system rather than a two-stage system; and (d) developing a robust system that is functional at a wide variety of dispersal and ignition conditions. These challenges are briefly described below.

Because JP-10 has a relatively low vapor pressure, it may be necessary to (a) pre-condition (e.g., heat) the fuel before dispersal, (b) develop a novel shock-heating concept, or (c) add a sensitizing agent to the JP-10 during dispersal. The proposal should discuss the system-level implications of the approach (e.g., preheating via integration into the delivery vehicle's thermal management system, logistical compliance of the sensitizing agent).

In single event FAEs, the fuel and ignition source are integrated and dispersed simultaneously or near-simultaneously; in a two-stage FAE, the fuel is dispersed first and then, after an appropriate time delay for cloud formation, the ignition system is activated. The time delay between events makes two-stage systems difficult to weaponize, particularly at high speed delivery (1000-3000 feet per second). A single event FAE might use a distributed ignition system that can be explosively dispersed with the fuel, such as a pyrotechnic material. The proposer should discuss the problems inherent to thermal ignition (versus shock ignition) if using this approach.

It is preferable, although perhaps not essential, that the FAE detonates rather than deflagrates. If a deflagration concept is proposed, the fuel-air explosive must generate a lethal impulse. Selection between detonation and deflagration modes is preferred but not required.

PHASE I: The contractor will develop the system concept or sub-system component through modeling, analysis, and breadboard development. Small-scale testing to show proof-of-concept is highly desirable. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and validate the component technology in a prototype based on the modeling, concept development, and success criteria developed in Phase I. Deliverables are a prototype demonstration, experimental data, a model baselined with experimental data, and substantiating analyses.

PHASE III: Contractor develops technology to TRL 5-6 transition in DoD acquisition program like Next Gen Cruise Missile. Private sector commercial potential fast, thermal decontamination of sites contaminated by hazardous materials like biological, chemical, or petroleum products, land clearing, deforestation.

REFERENCES:
1. Fan Zhang (editor), "Shock Wave Science and Technology Reference Library, Volume 4, Heterogeneous Detonation," ISBN 978-3-540-88446-0, e-ISBN 978-3-540-88447-7, Springer Verlag, Berlin Heidelberg, 2009.

2. AFRL Munitions Directorate Site: http://www.eglin.af.mil/units/afrlmunitionsdirectorate/

KEYWORDS: fuel-air explosive, FAE, warhead, munition, ordnance, explosive, detonation, deflagration

AF131-105 TITLE: Remote Interrogator for Munition Recorder Instrument Packages (RIMRIP)

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Design, build and test a system to remotely access and download munition test recorder data.

DESCRIPTION: Considerable effort has been expended on trying to develop test instrumentation packages (including accelerometers, power sources, memory, and other electronics) that can withstand the severe mechanical shock loads that occur in field tests of munitions systems. However, current systems in use require the physical recovery and subsequent direct interface with the recorder packages in order to obtain usable test data.

This is problematic for several reasons. Even minor deformation in the munition structure can make the removal and recovery of the instrument packages extremely difficult due to mechanical binding or failure of connections. The mechanical shock loads can introduce failures in the interface of the recorder package. The package must be recovered quickly (within the lifetime of the onboard battery system) for systems utilizing volatile memory. Compounding this problem is that the test articles often end up in situations where they are exposed to the environment for a considerable length of time, resulting in water or other damage and resulting in loss of data. Live tests using energetic materials also present a significant safety hazard, often preventing human manipulation of the test article and causing the data to be unrecoverable.

With the large cost associated with field tests, use of recorders that require recovery introduces significant risk. However, the increasing availability of non-contact remote technologies for accessing system data, such as inductively- or capacitively-coupled datalinks, provides an attractive mechanism for mitigating this mission risk and providing a needed test capability. A system that remotely interrogates and securely downloads data from instrument packages would represent a significant improvement over the current systems and greatly reduce the mission risk for field tests. It is expected that the technical approach will consist of at least two main subsystems: a remote interrogation/downloading "base station" system and a data transceiver that is embedded in the test article(s).

Thus, the objective of this SBIR is to identify novel concepts for a robust shock-hardened datalink to access and download data from fuze instrument packages embedded in munitions that can operate in difficult environments such as underwater or partially covered in dirt. The following features are required for a successful concept: (1) operation at greater than 50% maximum throughput when submerged in 5 feet of salt water; (2) operation with a minimum separation of 10 cm; (3) integrated, shock-survivable (to 20,000 g's) power system with average sustained power requirements for the test article component of less than 100 W; (4) ability to transmit encrypted digital data for up to 10 minutes at greater than 50 kB/s and receive encrypted commands for up to 5 minutes at 10 kB/s; (5) test article external interface/features with a surface footprint of less than 25 x 25 mm^2 and a total test article volume of less than 10 cm^3; (6) error-checking on the data transmission; and (7) shock-hardened encryption hardware.

The Phase I effort involves selecting a candidate scheme and developing the communications protocol. A limited amount of initial proof-of-concept testing is expected of critical components and subsystems, for example, characterization of the datalink properties while buried in dirt.

PHASE I:
1) Design a secure datalink that can be used to remotely access data on fuze instrument packages.
2) Validate critical operational components/subsystems in laboratory brassboard/proof-of-concept testing.

PHASE II:
1) Demonstrate the operation of the key components under severe mechanical loading.
2) Fabricate and test a full-scale prototype secure datalink.
3) Using available instrument packages, validate the system operation in wet and dusty environments.

PHASE III: Develop commercially viable variant. Implement for dual-use applications, including crash testing.

REFERENCES:
1. Munitions Directorate Homepage <http://www.mn.afrl.af.mil/>.

2. Military Handbook of Fuzes, MIL-HDBK-757(AR), 15 April 1994. (Public Releasable via USA Information Systems, Inc; www.usainfo.com, 757-491-7525).

KEYWORDS: Instrumentation, bidirectional communication, datalink, capacitive, inductive, magneto-inductive, non-contact, nondestructive, remote, interrogation

AF131-108 TITLE: Lightweight Electromagnetically Immune Wire and Composite Conduit

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: The primary objective of this topic is to develop and transition material technologies to enable HPM hardened composite conduit, endcaps/ mating surfaces (compatible with both composite and aluminum enclosures) and provide lightweight cable shields.

DESCRIPTION: Current shielding of power cables and signal cables including those use in fly-by-wire aircraft rely on heavy over-braiding utilizing multiple layers of braiding and foil wraps. These braided wires may add up to several pounds per yard in a traditional cable harness. In addition these cables may then be placed in a secondary metal shield such as a metal conduit, further adding weight to the aircraft. This additional weight can reduce mission time by increasing fuel use, and is not necessarily immune to low frequency RF events , both natural and manmade.

Both commercially scalable conductive nanotechnologies and recent advances in NON-parasitic conductive composite technologies present a unique opportunity to impact both the weight of the wiring system reducing fuel costs and the RF/ microwave electromagnetic performance of the shielding. This effort is to design, fabricate and test a system of both improved lightweight cable shielding and composite (carbon fiber or Kevlar based) conductive conduit which does not utilize metal foils or other parasitically attached structures. The system demonstrated must be retrofit compatible with existing standard metal enclosures such as those found in avionics flight surface actuator boxes as well as future conductive composite based aircraft enclosures / equipment racks.

The materials proposed in this effort must be scalable to mass production and not impose additional maintenance requirements over the baseline technology. The manufacturing processes proposed must utilize standard industrial equipment and industrial teaming is strongly encouraged to facilitate meeting this performance metric.

Anticipated deliverables would include multiple sections of lightweight signal and power cable >10m long as well as corresponding segments of lightweight composite conduit illustrating straight sections, flexible sections, 90 degree bends, 30 degree bends, 45 degree bends, T-segments, and Y-segments. The cable and conduit deliverables shall demonstrate the ability to be installed utilizing traditional tools and techniques, endure standard vibration and mechanical loading associated with standard flight profiles for tanker and transport aircraft as a minimum , with a goal of surviving loads and vibrations associated with modern fighter aircraft. The electromagnetic protection should not degrade under these loads. Electromagnetic testing shall be conducted at low powers utilizing MIL-STD testing techniques, including reverberation chamber testing. Electromagnetic testing shall also be accomplished against narrowband and wideband HPM sources at power levels to be provided to the successful bidder(s).

Contracts resulting from this solicitation will be ITAR restricted, and Phase II activities will require an existing facility clearance in place at the secret level. These requirements will flow down to subcontractors including universities.

PHASE I: The Phase I effort will demonstrate initial shielded cabling technologies and conductive structural conduit. Deliverables shall include a final & intermediate reports, Three 6 foot segments of best effort shielded cabling with shielded end connectors demonstrating the technology developed, three straight segment conductive conduit with shielded end connectors demonstrating technology developed.

PHASE II: The phase II shall build on the technology developed and results of the phase I testing. Deliverables shall include quarterly reporting, 12 of each of the bend segments describe in the description as well 12 of the corresponding structural conduits. The system shall be demonstrated against narrow and wideband HPM sources and with composite and aluminum enclosure terminations. The technology manufacturing readiness level will be matured to facilitate commercial transition.

PHASE III: Phase III efforts shall focus on technology transition for dual use domestic applications in commercial aircraft as well as specific DOD systems. A business model for the technology transition will be evaluated at the start of the effort and monitored during the course of the effort.

REFERENCES:

1. http://webbooks.net/freestuff/MIL-STD-464C.pdf.

2. http://www.tscm.com/MIL-STD-461E.PDF.

3. http://www.thomasnet.com/products/fittings-conduit-cable-aircraft-97005705-1.html.

KEYWORDS: HPM, High Power Microwave, shielding, hardening, EMP, HEMP, Conduit, Cables, conductive, structural, composite

AF131-109 TITLE: Selective Radio Frequency Shielding

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Investigate the feasibility for selective radio frequency (RF) shielding that will have the capability to block unwanted frequencies and pass only select narrow bandwidth frequencies.

DESCRIPTION: The Air Force Research Laboratory (AFRL) has made significant contributions to Electronics and Photonics for Air Force Systems. Through both in-house research and a recently completed contractual effort, very effective, composite/polymer-based, non-conductive, high thermal conductivity, radio frequency (RF) and electromagnetic interference (EMI) shielding has been demonstrated.[1,2] Non-conductive, high thermal conductivity, RF/EMI shielding allows microelectronic circuits and sensors to be RF/EMI shielded without electrical shorting by simply coating or spraying the material directly onto the circuit. High thermal conductivity has the potential to remove heat from the circuit, thus, increasing circuit lifetime. Being able to coat the circuit with RF/EMI shielding material also provides shielding between wires within the circuit as well, which becomes more crucial as processing and data rate speeds increase. The material can also potentially be used as a casing for external wires for RF/EMI shielding.

Composite materials, such as the polymer-matrices containing conductive fillers developed in AFRL, have proven very attractive for shielding RF/EMI due to their high shielding efficiency and seamlessness, processability, flexibility,light-weight and low-cost. It has been shown that a thin layer of this new composite-based (typically ~30 - 50 µm) can block RF/EMI radiations up to 60 dB effectively over an RF frequency range of KHz to tens of GHz, exhibiting excellent RF/EMI shielding effectiveness. A wide selection of metal and graphite nanoparticle/nanopowder fillers have been tested for their performance in RF/EMI shielding effectiveness. Among them, silver and carbon-based nanoparticles/nanopowders have demonstrated the best performance to date and can be easily rendered non-conductive, while preserving effective RF/EMI shielding.

The purpose of this effort is to determine if new materials can be developed to be radio frequency selective materials. To possess the capability to effectively block unwanted radio frequencies, while allowing desired radio frequencies to pass, enhancing the capabilities of current Air Force C4ISR systems. The basic idea is to ultimately design ultra-narrow-band RF filters which can be an RF counterpart to optical filters which block out certain wavelengths while allowing others to pass. For mobile platforms, such selective filtering is essential, as certain communication data from sensors, GPS, etc. needs to be transmitted and received, while the entire platform is shielded from RF and cannot be detected.

PHASE I: Process candidate selective radio frequency shielding materials for specific C4ISR device/devices and characterize these materials to show their suitability. The demonstrated characteristics of these materials will help determine whether to proceed onto Phase II.

PHASE II: Select RF component to fabricate and test RF devices using the selective radio frequency shielding materials developed during Phase I and compare them with any currently implemented devices. Also, continue with materials development by optimizing the selective radio frequency materials developed during Phase I, and/or processing new selective radio frequency materials in order to optimize the performance of the device/devices under development.

PHASE III: Integrate RF component fabricated in Phase II onto the selected airborne platform, and conduct field testing to evaluate RF shielding performance.

REFERENCES:

1. D. Zang and J. Grote, “DNA-Based Nanoparticle Composite Materials for EMI Shielding”, SPIE Proceedings, 8259, DOI: 10.1117/12.905284 (2012).

2. D. Zang, “Biotronic Sensors for Cost, Size, Weight and Power, and Enhanced Bandwidth (C-SWaP-B) - DNA-Based EMI Shielding Materials (DESM)”, Air Force Research Laboratory Technical Report, AFRL-RX-WP-TR-2012-XXXX, (2012).

KEYWORDS: electromagnetic interference, radio frequency, shielding, nonconductive, polymer

AF131-110 TITLE: <u>Electromagnetic Hardened Composite Enclosures for Aircraft Systems</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: The overall objective of this topic is to demonstrate transitionable composite based enclosures suitable for protecting sensitive electronics from harsh electromagnetic environments such as High Power Microwave and Electromagnetic Pulse.

DESCRIPTION: The traditional solution to electromagnetically hardening aircraft avionics (flight surface control hardware) enclosures, as well as sensitive electronics such as communication racks is to build heavy steel or aluminum boxes upwards of an inch thick, in which the electronics hardware is mounted. This adds excessive weight to the aircraft, reducing fuel efficiency / payload capacity; adds additional mechanical loads to the airframe resulting in increase structural maintenance or structural modifications.

Composite based materials offer a lightweight and affordable opportunity to address the current electromagnetic environments experienced by aircraft as well as designing in protection for emerging requirements such as High Power Microwave (HPM) and Electromagnetic Pulse (EMP) protection which has typically been waivered from programs due to cost and weight constraints of current metal solutions. This effort endeavors to produce affordable, corrosion immune, transitionable material technologies and hardware enclosures that demonstrate a significant advance in the state of the art in electromagnetic shielding. The enclosures shall demonstrate a 50 to 70 percent weight savings over traditional metal enclosures, demonstrate mechanical robustness to withstand traditional vibration and weight loads associated with standard flight profiles given the weight distribution of electronics placed within them. The enclosures shall meet or exceed applicable MIL-STD-461 , MIL-STD-464, MIL-STD-2169B requirements. Technology developed must be compatible with standard manufacturing practices in order to be considered affordable and transitionable. Examples of standard manufacturing practices are (but are not limited to) compression molding, injection molding, autoclave manufacturing, and emerging out of autoclave techniques currently used in industry. Technologies developed should be pervasive and meet broad hardening requirements as well as be scalable to manufacturing of both small and large enclosures. A secondary technical consideration is thermal management of the electronics in the enclosure. Technologies demonstrated should address passive methods for heat removal from electronic components they contain; the use of liquid cooling is not acceptable.

This effort will inherently be ITAR restricted in both the Phase I and Phase II efforts. The Phase II effort will require a facility clearance. Awards resulting from this topic will have security / ITAR flow down requirements to subcontractors and universities in both the Phase I and Phase II efforts.

PHASE I: The phase I activity will consist of demonstrating electromagnetic performance relative to metal analogs. Deliverables for the Phase I shall include a technical report detailing the technology developed and how it specifically addressed the goals defined in the description, a prototype demonstration showing proof of feasibility such as an enclosure roughly 12x24x6 inches in size.

PHASE II: Phase II shall mature the technology from the phase one and in addition demonstrate the full mechanical, thermal and manufacturing scalability required to meet the goals defined in the description. Deliverables include quarterly progress reporting, full size, form, fit, function enclosures designed to specifications to be provided at the time of the Phase II award.

PHASE III: Industry partnership and transition of the technology for dual use in domestic commercial air and/or automotive systems as well as DOD platforms is to be accomplished.

REFERENCES:
1. http://web books.net/freestuff/MIL-STD-464C.pdf.

2. http://www.tscm.com/MIL-STD-461E.PDF.

3. http://documentsearch.org/pdf/mil-std-2169b-high-altitude-electromagnetic-pulse-hemp-environment.HTML.

KEYWORDS: HPM, EMP, HEMP, electromagnetic, enclosure, aircraft, composite, hardening

AF131-111 TITLE: Cold Temperature Hydraulic Seals for Aerospace Hydraulic Systems

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Design and demonstrate a high pressure hydraulic sealing solution for a dynamic sealing application that is compatible with Military Red Hydraulic Oils and Nitrogen gas down to temperatures of -100 degrees F.

DESCRIPTION: Aircraft hydraulic systems have traditionally been required to operate down to -65 degrees F. However, with the advancement of unmanned air vehicles, operating envelopes at high altitudes are evolving. Unmanned Air vehicles are loitering at high altitudes for upwards of 24 hours. As a result, sections of the hydraulic system are becoming cold soaked and prone to leakage. The current solution is to wrap hydraulic components in heater blankets, which add complexity and weight and require electrical power. USAF and NAVAIR seek hydraulic sealing capability for components capable of operating up to 5000 psi, in Mil-PRF-83282, Mil-PRF-87257, MIL-PRF-5606 hydraulic oil and Nitrogen gas. These seals should be capable of sealing in storage down to -100 degrees F and operation from -70 degrees F up to 160 degrees F (Objective: 275 degrees F) in order to reduce or eliminate leakage experienced while operating in cold soaked environments. Proposed efforts can encompass any size seal and configuration that would be compatible with AS 4716 standard seal gland design specification. It is not anticipated Government Furnished Equipment (GFP) will be required for this effort.

PHASE I: Identify, develop, and prove feasibility of concept for a high pressure hydraulic sealing solution for a dynamic sealing application that is compatible with Military Red Hydraulic Oils and Nitrogen gas down to temperatures of -100 degrees F.

PHASE II: Develop a prototype sealing solution and demonstrate implementation into an AS 4716 seal gland capable of sealing in storage down to -100 degrees F and operation down to -70 degrees F. Identify target platform for integration of the sealing technology.

PHASE III: Perform validation and certification testing to transition the approach to the target fleet and other candidate platforms. Other candidate military platforms include NASA high altitude research vehicles and surveillance platforms for homeland security. Commercial applications include sealing on platforms used for high altitude weather surveillance, and monitoring of hurricanes and forest fires.

REFERENCES:
1. AS-5440

2. AS-8775

3. AS-4716

4. MIL-PRF-83282

5. MIL-PRF-87257

6. MIL-PRF-5606

KEYWORDS: Materials, hydraulics, seals, Hydraulic Components, Cold Temperature

AF131-112 TITLE: Alternate Faceplate Materials for Improving Image Intensifier Tube Performance

TECHNOLOGY AREAS: Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop Improved Performance Image Intensifier Tubes by Utilizing Alternate Faceplate Materials

DESCRIPTION: An Image Intensifier Tube is an electro-optical device which converts photons to electrons, amplifies them, and then converts them back to photons so the user can see at light levels that are normally too low. These Image Intensifier Tubes are commonly used in night vision goggles and night scopes to allow vision in low-light level conditions.

The main components of modern Image Intensifier Tubes are a faceplate, photocathode, multichannel plate, and phosphor screen.

This purpose of this effort is to develop Image Intensifier Tubes with alternate faceplate materials for improved performance and compatibility with USAF systems. Historically, the faceplate has been 5.537mm thick Corning 7056 glass, or equivalent (MIL-L-49426). There are several potential advantages to using faceplate materials other than Corning 7056 glass. These include higher quality Modulation Transfer Function (MTF) performance, spectral filtering, and ease of processing.

The Image Intensifier Tube faceplate is an integral component of the objective lens assembly in Night Vision Goggles. Replacing the current faceplate with an alternate one having higher refractive index opens the possibility of new optical designs with reduced aberrations. In addition, alternate materials – such as chalcogenide glasses – can be patterned in ways that may increase light collection, including the implementation of microlens structures on the faceplate. Alternate faceplate materials may also offer advantages for compatibility with cockpit display standards.

The performance figure of merit (FOM) for night vision goggles is derived from the number of line pairs per millimeter multiplied by the tube's signal-to-noise ratio.

PHASE I: Demonstrate the feasibility of incorporating alternate, high refractive index, faceplate materials into Image Intensifier Tubes. Investigate methods for improving sensitivity and lowering signal to noise ratio; These Image Intensifier Tubes must retain similar performance (FOM should be equal to or greater than 1400) to standard tubes including size and weight.

PHASE II: Optimize selection of alternate faceplate materials for enhanced MTF performance. Analyze impact of Image Intensifier Tubes incorporating alternate faceplate materials on objective lens design and performance. Validate FOM performance equal to or greater than 1400. Deliver prototype Image Intensifier Tubes with alternate faceplate materials to the government for additional testing and comparative demonstration with current image intensifier tubes.

PHASE III: Perform Manufacturing Readiness Level Assessment. Optimize manufacturability of Image Intensifier Tubes made with alternate faceplate materials.

REFERENCES:

1. Image Intensifier Tube Performance is What Matters; Leon A. Bosch, SPIE Proceedings Vol. 4128, Image Intensifiers and Applications II, 2000, pp.65-78.

2. Night Vision Devices and Image Intensifier Tubes; Nikolay F. Koshchavtsev, SPIE Proceedings Vol. 4369, Infrared Technology and Applications XXVII, 2001, pp. 81-85.


KEYWORDS: Image Intensifier Tubes, Night Vision, Low-Light Level Detectors, Optical Faceplates

AF131-113 TITLE: Radio Frequency (RF) Traveling Wave Inspection Tool

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a non-destructive Radio Frequency evaluation tool for aircraft specialty coatings.

DESCRIPTION: Specialized aircraft coatings can degrade over time and impact desired performance. Currently, waveguide reflectometers are used as an RF point inspection tool for on aircraft measurements. Current reflectometers measure at normal incidence or 90 degrees to the surface which does not accurately predict the electrical performance of the material across the aircraft's surface. It is desirable to measure the interaction of the non-specular component or traveling wave to fully characterize the electrical performance of the coatings.

A new RF hand held measurement device is desired that is capable of making true traveling wave measurements excited between 5° and 20° to the surface. The device should be able to determine the attenuation per unit length (i.e.: dB/in) of a surface wave that is excited on the surface of the aircraft. It is desirable to measure this performance across the frequency band of 2-18 GHz. It is acceptable to have multiple devices to cover this frequency band, but not more than four. A single broad-band probe is highly desirable. The probe will be used on fielded air vehicles and cannot damage the surface being measured. The device should pose no safety hazard to personnel or equipment and can be used in an aircraft fueled environment. It shall be capable of being approved for flight line operation. The surface will not typically be flat and therefore should conform to the surface being tested. Assume that the probe must accommodate surfaces from flat to a compound radius of curvature of 50 inches. Ability to support higher radii of curvature is desirable. The probe should fit within a 12" by 12" area on the aircraft. A smaller footprint is desirable. It is anticipated that the probe will work in conjunction with a government furnished vector network analyzer. The analyzer is a two port instrument and it is desirable that the probe not require additional ports, access to analyzer may be arranged. The probe shall not impact analyzer battery power more than 20%. A standalone device or one that utilizes special test equipment is acceptable. It is expected that this probe will be transportable and operable by a single technician.

PHASE I: Perform research relevant to surface wave excitation, attenuation and understand the challenges and goals of this program. Use commercially available magnetic materials as required. Develop methods on how to measure surface wave attenuation provided by the application of coating. Perform trade studies on the various concepts and down-select an approach that will be prototyped in Phase II.

PHASE II: Design and fabricate the probe identified in Phase I for performing measurements in a lab environment. Results obtained should be verified with other methods of characterizing material performance. Extraction of material permittivity and permeability using standard techniques and analytically determining the surface wave attenuation is acceptable. A method of moving the probe along the surface while collecting data at predetermined locations should be explored for feasibility and utility.

PHASE III: A probe suitable for flight line field use shall be demonstrated. Must be suitable for use in a hazardous vapor environment defined by the National Electric Code, Class I, Division 2. Probe shall not require modification to the surface being inspected nor shall it damage a typical painted surface.

REFERENCES:
1. Richmond, J.H., Peters, L., and Hill, R.A., "Surface Waves on a Lossy Planar Ferrite Slab," IEEE Trans. Antennas and Propagation, AF-35 (7), 1987.

2. Collin, R.E., "Field Theory of Guided Waves," 2nd ed. IEEE Press, Piscataway NJ, 1991, pp. 712-718.

3. Klopfleisch, M. and Schellenberger, U., "Experimental Determination of the Attenuation of Surface Electromagnetic Waves," J. Appl. Phys., 70 (2), 1991.

KEYWORDS: Radio Frequency, RF, Measurement, Traveling Wave, Attenuation, Reflection, Reflectometer.

AF131-114 TITLE: Automated aircraft inlet coating

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop an automated system/method to apply coatings in aircraft inlets that have complex geometries. The trade-offs between cycle time, cost, accuracy, reliability, and complexity should be considered while developing a solution to the objective.

DESCRIPTION: Many high performance aircraft inlets are designed with complex geometries and require specialty coatings of exact thickness to meet design requirements. During production, aircraft manufacturers typically apply inlet coatings to the duct prior to assembly. Often final assembly requires permanent bonding or fastening of the duct to the fuselage and thus future disassembly is not possible. Between overhauls, i.e. in the field, coatings often need to be replaced, thereby increasing aircraft downtime. An automated coating application capability is needed that can apply coatings in an engine inlet duct with high precision while on an aircraft.

In service, the engine inlet coatings life can be shortened by foreign object damage. Between overhauls, i.e. in the field, this damage needs to be repaired, thereby increasing aircraft downtime. Currently, aircraft engine inlet coatings are sprayed manually when being restored in the field or depot. This requires a maintainer to climb into a confined space carrying all necessary equipment and supply lines while donning a significant amount of personal protective equipment (PPE). A significant number of hazards exist for workers in such conditions and the variability of applied coatings is increased due to these constraints.

Therefore, the proposer of a solution to this problem is asked to develop an automated system/method to apply coatings in assembled aircraft inlets that have complex geometries. The automated application technology must be able to apply coatings at exact thicknesses, which varies from location to location in an inlet duct. In order to avoid the undesirable variability of thickness that can occur with hand spraying, this effort should leverage recent developments of in-situ, non-contact thickness monitoring of coatings as well as work done in determination of the location as to where the coating is delivered. The ability to re-coat an entire inlet as well as repair small areas or strips of damage is desired. The automated system must not damage the structure of the aircraft. A fielded automated coating system may need to be used in a fueled environment. Expedient repairs are desirable to return the aircraft to service as quickly as possible. To that end, inlet coating may be best accomplished with the engine removed. A submitter is asked to consider the time lines associated with engine removal versus ease of application and determine the best strategy.

PHASE I: Determine if an automated inlet coating system is feasible. Describe the proposed method/system and operational requirements. Consider two designs: one that is used in a depot environment and one that it is forward deployed. The trade-offs between cycle time, cost, accuracy, reliability, and complexity should be considered in the analysis.

PHASE II: Conduct a demonstration under depot-like conditions with the proposed automated inlet coating system on a small-scale inlet duct. Demonstrate the ability to deliver differing prescribed amounts of coating at various locations within a contorted shape, to be defined by the Air Force, of approximately 72" x 36" x 18". Refine the analysis of cycle time, cost, accuracy, reliability, complexity, and operational requirements for the two designs.

PHASE III: Expand system capability so it could be used at forward deployments. Demonstrate or propose design changes so it could support multiple platforms, i.e. aircraft with small duct sizes or open inlets. Propose design changes that would enable the system to do automated sanding of the applied coatings.

REFERENCES:


1. http://usmilitary.about.com/od/airforceenlistedjobs/a/afjob2a7x3.htm.

2. http://www.holloman.af.mil/news/story.asp?id=123279167.


KEYWORDS: coatings, aircraft inlet, coatings

AF131-115 TITLE: Nondestructive Evaluation of Thick Outer Mold Line Paints and Coatings

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: A nondestructive evaluation tool for aircraft outer mold line (OML) urethane and epoxy integrity assessment to address and identify premature failures.

DESCRIPTION: Many paints and coatings are employed on modern military aircraft with functionalities such as rain erosion resistance or p-static dissipation. These paints and coatings experience a wide variety of environmental conditions in flight and on the ground. While performance degradation over time is expected, the Air Force is experiencing a number of premature failures of urethanes and epoxies used on the Outer Mold Line (OML) of high performance aircraft. Standard material lifetime predictions fail to estimate urethane lifetime on operational aircraft due to the wide variety of environmental factors and combinations of factors that trigger degradation at different rates. While signs of urethane aging may not be visible, the onset of chemical composition and physical properties changes can occur. A significant ongoing Air Force investment is being made to understand the cause and extent of these material failures. While these studies will serve to characterize failure mechanisms and evaluate material performance under a variety of relevant conditions, permitting a better understanding of environmental degradation and a refinement of lifetime prediction models, there is no currently demonstrated technology capable of evaluating the in-place integrity of epoxy or urethane materials on a fleet. Representative damage modes that need to be detected are mentioned below. Therefore, the focus of this topic is not on cause and effects studies. The Air Force desires a nondestructive capability for the rapid in-place determination of the integrity of Aircraft OML urethanes and epoxies. The measurement technology must be capable of interrogating a variety of multi-layer coating systems and providing an assessment of total coating system integrity as well the ability to discriminate and characterize individual sub-surface layers. The assessment of coating material state and system integrity should be based on the analysis of measurable quantities which change with respect to the type and degree of material degradation. Detection of changes such as corrosion of fillers and pigments as well as bond breaking and out-gassing of the matrix are the focus of this solicitation for determining the material state of a paint or coating system. The measurement technique must be nondestructive and non-invasive and permit early detection and trending of a detrimental parameter associated with degradation. This measurement capability is desired so that aging materials can be assessed in-place enabling accurate planning and budgeting for sustainment operations.

PHASE I: Develop a laboratory urethane based paint and coating integrity evaluation tool for measurement and analysis of a two or more layer material subjected to various degradation conditions. The applicability of the method for epoxy based paints should also be addressed with an experimental plan for phase II. The ability to differentiate and determine the integrity of each coating is required.

PHASE II: Demonstrate a nondestructive measurement capability on a stack of four representative OML materials subjected to various degradation conditions. No government furnished equipment is anticipated. Demonstrate the ability to track degradation levels of the system and the individual layers. Develop a plan for packaging, ruggedization and commercialization of a man portable inspection tool for on-aircraft measurement. Develop/demonstrate a prototype OML coating inspection and assessment tool.

PHASE III: Development of a man portable, ruggedized, in-place coating inspection tool will have military applications for many systems employing epoxy and urathane based paints and coatings. Other applications could include commercial air and automotive industries.

REFERENCES:
1. Detection and Characterization of Water-induced Reversion of Epoxy and Urethane Potting Compounds, DTIC Final Report, 10 Oct. 1976 - 10 Oct. 1977, Jakobsen, A. J.

2. Analyses for Mechanical and Electrical Properties of Epoxy Resins Used as Potting Compounds, Polymer Engineering & Science, Vol. 14, Issue 6, PP. 478-480, June 1974, Fountain, R.

3. Failure Analysis of Paints and Coatings, John Wiley and Sons, Ltd., 2009, Dwight G. Weldon.

4. Mechanisms of Military Coatings Degradation, J.A. Escarsega, W.S. Lum, and P.H. Patterson., DTIC Final Report, Aug 2003.

KEYWORDS: NDE, NDI, Paint, Coating, Topcoat, Sealant, Urethane, Epoxy

AF131-116 TITLE: <u>Decision-Support Technologies for Weapon System Sustainment Processes and Life Cycle Investment</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The objective is to develop technologies which extend sustainment modeling and simulation capabilities to support improved investment decisions throughout the weapon system lifecycle.

DESCRIPTION: This will be accomplished by providing comprehensive, structured, integrated, and repeatable simulation capabilities to model detailed sustainment processes and factors encompassing unit maintenance, supply chain management, depot operations, constrained resources, and reliability, availability, maintainability, and supportability (RAMS). This will provide the capabilities and support necessary to ensure that interactions and dependencies across the enterprise are captured and addressed within the contexts of overall system readiness and cost.

Simulation plays a critical and increasing role in analysis, determination, and verification of requirements for system capabilities and readiness not only during initial acquisition phases, but also throughout modernization and sustainment. A thorough, structured, and integrated simulation capability that is applicable across the enterprise and that can address the spectrum of sustainment issues is therefore critical to inform and support investment decisions throughout the entire life cycle.

Reporting of system availability, reliability, and cost have been mandated as key performance parameters (KPPs) and system attributes (KSAs) by the Office of Secretary of Defense (OSD). Current simulation tools such as the Logistics Composite Model (LCOM) now offer capability to generate the required KPP and KSA metrics. While these simulation tools are detailed and community accepted, they are specialized and focused on unit maintenance, resources, and RAMS. Other tools may address supply chain and depot operations, but do so only with a corresponding specialized and narrow focus on sustainment. Still other tools may address a wide range of factors, but they lack sufficient detail for the credible results needed for sustainment planning in a budget constrained environment.

A new simulation capability is needed which combines simulation tools for the detail required for credible results and integrates a thorough capability to model multiple processes and factors including unit maintenance (scheduled and unscheduled), supply chain management, depot operations, management and planning (including scheduling), resource constraints (spares, manpower, support equipment, facilities), and system reliability, maintainability, availability, and supportability (RAMS). This would enable a robust and repeatable capability to ensure that technology, system, and process initiatives can be evaluated, analyzed, and optimized with an integrated strategy to provide the greatest return for budgets under ever increasing scrutiny and pressure for downsizing. It would also provide capability to support analysis and initiatives such as level of repair analysis (LORA), and efforts supporting depot operations such as High Velocity Maintenance (HVM).

Current modeling and simulation tools and applications offer critical capabilities that are specialized, effective, proven, and accepted. Leveraging these successful and credible tools for enhancement and integration should be considered and maximized where practicable.

The intended application should make use of existing software standards and offer data commonality amongst tools, innovative visualization, and collaborative interfaces amongst users and other simulation tools. Existing workstations with standard operating systems is the desired platform.

Familiarity with existing AF maintenance and logistic data systems and relevant modeling and simulation tools is desired.

PHASE I: The researcher will identify the new simulation capabilities and requirements, and develop an integration concept for the new methodology. The researcher will identify measures and components, and outline the structured approach to integration and operation. The researcher will develop a proof of concept demonstration of feasibility.

PHASE II: The researcher will further design, develop, document, and demonstrate a structured and integrated simulation capability to extend sustainment modeling and simulation capabilities to support improved sustainment decisions throughout the weapon system lifecycle. The researcher shall develop and provide a demonstration of the simulation capability. The researcher will develop a plan for potential Phase III efforts.

PHASE III: The Phase III product will be a robust, off-the-shelf, collaborative and integrated simulation capability for use in evaluating process improvements and sustainment enhancement options for defense and commercial product research, development, operations, and manufacturing.

REFERENCES:
1. Aeronautical Systems Center Logistics Composite Model (Defense Acquisition University) https://dap.dau.mil/aphome/das/Lists/Software%20Tools/DispForm.aspx?ID=53.

2. High Velocity Maintenance (Air Force Magazine, August 2009) http://www.airforce-magazine.com/MagazineArchive/Documents/2009/August%202009/0809maintenance.pdf.

3. Department of Defense Reliability, Availability, Maintainability, and Cost Rationale Report (The Reliability Information Analysis Center) http://www.theriac.org/pdfs/DoD-RAM-C-Manual%202009-06-01.pdf.

KEYWORDS: reliability, availability, maintainability, supportability, sustainment, cost, depot, maintenance, modeling, simulation, logistics, supply chain, high velocity maintenance

AF131-118 TITLE: <u>Innovative Methodology for Composite Structure Allowables and Analytical Validation</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a methodology for composite structure design allowables leveraging analytical techniques and existing test databases to validate methods of prediction for composite material properties, allowing reduction of future design allowable matrices.

DESCRIPTION: Composite materials are widely used in DoD programs; however each new material system, form (tape grade, fabric weave, resin content, etc), and layup process (e.g., tape hand layup, tow placement, automated tape layup) requires a large, costly, time-consuming test program for allowables, design values, structural properties, and subtle property variations. This often inhibits the use of new material systems. Nevertheless, surprises uncovered during weapon system development and test often necessitate the introduction of new material/process solutions without the time and budget luxury afforded with traditional test programs.

Large test databases are now available for a significant number of carbon fiber reinforced plastic (CFRP) materials, both from DoD programs and industry shared databases, such as NCAMP. Initial evaluations of data from multiple material systems indicate that general property trends, such as ratios of notched to unnotched strength, and bolted joint geometry factors, are consistent across material systems. However, since many of these trends are subtle, complicated, and confounded by material and testing variations, very large datasets are necessary for development of accurate property models. Data for large numbers of batches (tens to hundreds) and identical data-points (hundreds to thousands) are needed to evaluate subtle effects and overcome apparent discrepancies seen in small 3 to 5 batch datasets. The database size issue can now be addressed as sufficient material systems have been used for a number of years on production programs, providing not only large initial allowables and qualification databases but also on-going production batch acceptance data. Further, test method bias and error is the source of many apparent differences within and between databases. The property correlation effort must isolate these issues and problems with a combination of test method subject-matter-expert judgment and statistical analysis in order to minimize test method influence on property estimation.

Analytical methods incorporating advanced material failure and damage models have shown promise for use in composite material property prediction. There is a significant potential and benefit for reducing composite material test programs by leveraging existing material property data combined with analytical methods for filling out and extending the property trends. Well documented structural level property trends and factors linked to fundamental material properties will provide a robust database for validation of current and future analytical methods; successful validation of improved analytical methods has the potential for further reduction in material and structural test programs, and corresponding acceleration of insertion of new material systems.

In Phase I, it is recommended that proposers should seek to leverage as much data as is currently available through interaction with Prime contractors, material suppliers, and weapon system program offices. A commercialization plan should be included as part of the Phase I proposal and refined in preparation for Phase II. The work should also describe how the empirical data correlations can validate the analytical method and how future test programs could be reduced in scope as a result.

During Phase II, the database correlation should be tested by using data from a material not found in the database or with data developed during Phase II. As a deliverable, several copies of the software with instructions/user manuals should be delivered for test and validation by the government.

PHASE I: Obtain/construct database of DoD/industry CFRP test data at coupon/element levels. Develop initial cross-material correlation & factors linking to 1 related mech property (e.g. compression, tension, etc). Remove test method bias effects. Evaluate trends of different forms of the same material. Assess analytical methods for property prediction & demonstrate correlation to empirical data trends.

PHASE II: Expand database to glass and quartz. Develop cross-material correlations for properties. Avoid bias from test differences/small databases. Develop software with property correlation, trends, and factors. Generate full range of design values with input of key test data. Document key tests required to characterize a new material system and demonstrate by correlation. Validate analytical predictions on a range of property trends. Write instructions for the test procedures and manuals for software.

PHASE III: Upon meeting the customer's validation requirements, the composite material allowables program approach and associated analytical methods will be incorporated into the airframe development process. The computer code supporting the methodology will be available as a commercial product.

REFERENCES:

1. Composite Materials Handbook, CMH-17.

2. JSSG 2006.

3. http://www.niar.wichita.edu/coe/ncamp.asp.

4. H Bau and D M Hoyt, "Global Approach to Characterizing Composites Strength with Empirical, Analytical and Progressive Damage Methods", STTR AF96T009 Phase II, SVELT Workshop, AF Materials Directorate, 2000.

5. H Bau, Damage and Failure Mechanisms in Composite Bolted Joints, ASTM Symposium on Joining and Repair of Composites Structures, Kansas City, 2003.


KEYWORDS: composites, modeling, structural properties, structural testing

AF131-119 TITLE: Robust Methods for the Measurement of Bulk Residual Stress

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop robust methods to measure bulk residual stresses in complex aerospace structural components.

DESCRIPTION:  Novel methods are sought for reliable bulk residual stress measurement in metallic aerospace components. These methods are desired to support the use of residual stresses for engineering benefit to include enhanced fatigue performance, stress corrosion cracking resistance, and/or enhanced damage tolerance.

Aggressive performance and weight objectives are driving aircraft and engine manufacturers toward the use of advanced materials and structural concepts that may have inherent, process-induced residual stresses in localized, but critical areas. Certification of these components and structures will require that the influence of these residual stresses be properly accounted for during design. For example, the unitization of lugs and fittings with primary spars and bulkheads in airframe structure is being done in order to reduce part count, which, in turn, reduces the necessity for large numbers of fasteners and the associated hole preparation/mating requirements. Such unitization can be achieved through the use of large forgings which often have significant residual stresses in localized areas even after final machining. Since the primary structural elements for man-rated flight vehicles are typically designed based on damage tolerance concepts, this requires that fatigue crack growth analyses address the influence of residual stress on crack growth. Thus, robust methods to measure reliably the bulk residual stress will greatly facilitate the design and manufacture of unitized airframe structures. Similarly, engine designers are now considering the use of dual microstructure turbine disks to obtain optimum local properties while minimizing component weight. Hence, robust measurement techniques will benefit both aircraft engine and airframe components.

Several methods exist for determination of surface and near surface residual stresses, including, but not limited to, x-ray diffraction, hole drilling, slitting, and speckle pattern interferometry. These methods are sufficient for near surface applications, but are insufficient for the determination of stress states throughout large components or bulk materials. Methods with enhanced capability for the determination of residual stresses at significant depths are available (e.g., neutron and high-energy x-ray diffraction techniques), but these typically require access to specialized physics facilities which greatly restricts their viability in a production environment.

Desirable attributes of proposed techniques include:

1. Being capable of measuring bulk residual stresses in a wide range of aerospace structural alloys, especially Al and Ti airframe alloys (e.g., AA7085, AA 7050, AA 2024, Ti-6Al-4V).

2. Being capable of providing accurate measurements in challenging metallic microstructural environments to include large grains and high levels of crystallographic texture.

3. Having the ability to measure high residual stresses (i.e., stress values > 50% of yield strength).

4. Having the ability to measure residual stresses in a high residual stress gradient; a rationale for estimating measurement error should be proposed.

6. Being capable of operating reliably in a production environment.

7. Nondestructive methods are desirable but not mandatory.

In addition, the physics/mechanics underpinning the proposed method should be well understood and methods with some previous experimental proof of concept are favored.

PHASE I:  Demonstrate a prototype bulk residual stress measurement capability in a laboratory environment using a blind study to validate the method. Government furnished specimens will not be provided. With assistance from the TPOC verify relevance and viability of the approach with perspective users. Particular attention should be given in the proposal to the validation protocol of the technique.

PHASE II:  Develop and construct a fully functional demonstration system capable of performing surface residual stress analysis for a representative aerospace component such as an aluminum airframe component. With assistance from the TPOC demonstrate the capability for at least one relevant application with at least one prospective end-user.

PHASE III: Military Application: The technology developed is applicable to the design of lighter weight, unitized airframe structure. Commercial Application: Commercial airliners and military transports have similar airframes; thus, the technology is applicable to the design of lighter airframe structure.

REFERENCES:

1. J. Lu (Ed.), Handbook of Measurement of Residual Stresses, Prentice Hall PTR, Englewood Cliffs NJ, 1996.

2. M.B. Prime, "Cross-Sectional Mapping of Residual Stresses by Measuring the Surface Contour After a Cut," Journal of Engineering Materials and Technology, 123, 162-168, 2001.

3. M.B. Prime, R.J. Sebring, J.M. Edwards, D.J. Hughes, and P.J. Webster, "Laser Surface Contouring and Spline Data-Smoothing for Residual-Stress Measurement," Experimental Mechanics, 44(2), 176-184, 2004.

4. M.B. Prime, "Residual Stress Measurement by Successive Extension of a Slot: The Crack Compliance Method," Applied Mechanics Reviews, 52, 75-96, 1999.


KEYWORDS: airframe structure, aluminum, titanium, bulk residual stress, damage tolerance, fatigue properties, stress corrosion cracking

AF131-120 TITLE: Hand-Held Fastener Surface Measurement

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: Develop a handheld non-contact device that captures profiles of finished and unfinished aircraft surfaces. The device should also measure surface profiles of filled and unfilled fasteners relative to the surrounding surfaces.

DESCRIPTION: Current methods of measuring fastener flushness in production of fifth generation fighter aircraft center on manual measurements using a three-foot dial indicator. This method has been proven to be minimally capable to measure flushness to the production installation tolerance requirements. Hand-held laser line scanners are also used; however, these devices only scan a single line of data across the surface to be measured. This information does not give the operator enough information to make a decision as to whether rework is necessary or whether tight tolerances have been achieved.

There is a significant need for a handheld device that can capture, analyze and visually communicate to the operator, the surface profile of a small area that includes a fastener head surrounded by structure. Most development in the area of non-contact surface profile characterization is for systems which scan large areas covering many fasteners and don’t address localized scans. These large systems, while capable, are cumbersome and require significant computer skills and expensive capital investment. These systems also require time consuming setup and calibration prior to use and are not cost effective for smaller fastener count applications or limited line of sight access.

A handheld device would provide the simplicity to be used by typical quality assurance personnel, aircraft assembler, or depot/field maintainer. This device would be highly portable and user friendly (ie, weighs less than five pounds, communicate data via a wireless/self contained system, and battery powered to support at least one shift or eight hours of continued operation). The initial rough order of magnitude (ROM) of cost for this unit should be $5,000 or less. The device would be primarily used for fastener flushness and fill verification and” high fastener” troubleshooting activities. Other potential applications could be countersink depth measurement & seam validation of installed panels and filled gaps. It would be beneficial if the unit used existing data analysis software and was wireless with the ability to upload data to a computer for subsequent analysis.

The desired measurement speed is less than two seconds per measurement of the individual fastener. Data collection should provide for go/no go indication of individual features to the operator. Required countersink depth measurement is repeatable within +/- 0.0015". Fastener flushness measurement is repeatable within +/-0.0025".

Filled or capped fastener flushness is repeatable within +/- 0.0005".  (Additional information will be provided during the solicitation period via the SITIS website.)

Proposals that seek teaming arrangements with aircraft prime contractors are encouraged to facilitate transition. It is strongly encouraged that the Phase II Design of Experiments test plan and execution be developed in coordination with an appropriate prime contractor and program office so that the data is of most use in determining system performance and readiness for use.

Overall, the goal of this SBIR is to deliver a prototype unit that delivers requirements at an affordable cost. Phase I should focus on demonstration of a "proof of concept" and Phase II should focus on development, delivery, and initial field testing of a prototype. Both phases should include business case analyses, manufacturing assessments, and transition plans. Proposals that seek to perform "trade studies" or "technology surveys" are NOT encouraged - the focus is on providing demonstratable hardware at the end of Phases I and II.

PHASE I:  The focus of Phase I is on the demonstration of a proof of concept non-contact measurement system to measure fastener flushness. Perform analysis of scanning resolution at multiple fields of view would be performed to identify optimal operating parameters. Perform initial business case analysis, manufacturing assessment, and transition plan.

PHASE II:  Develop prototype unit based Phase I development. Perform Design-Of-Experiments (DOE) based testing to qualify measurement capabilities of prototype device. Deliver a prototype and perform initial field testing. Based on test results, identify (and perform if possible) required iterative modifications. Update business case analysis and manufacturing/transition plan.

PHASE III:  Perform remaining testing/modification to certify for use in an aircraft manufacturing/field environment. Deliver a unit that is optimized for manufacturing and affordability that will be available for purchase by the Department of Defense, other government agencies, and equipment manufacturers. Potential commercial applications include commercial aircraft manufacturing as well as land/sea vehicle manufacturing, or applications where tight tolerances for fastener installation are needed.

REFERENCES:
1. Alberts, Daniel G.; Countersink Depth Gauge, US Patent Number: 5758433, Filing date: Apr 23, 1996, Issue date: Jun 2, 1998.

2. Greenslade, Joe; Inspecting Countersunk Screw Heads, http://www.greensladeandcompany.com/pdf/Inspection-Flat%20Head%20Screws.pdf.

KEYWORDS: fastener flushness, non contact measurement, metrology

AF131-121 TITLE: Mitigating Sensor Saturation through Image Processing Techniques

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE:  Develop Image Processing Techniques to Mitigate Saturation Effects of MWIR cameras.

DESCRIPTION:  Air Force tactical and reconnaissance platforms rely on high performance, multifunctional optical sensor systems. The primary optical sensor in these systems is a Mid-Wave Infrared (MWIR) camera because it combines high resolution imagery with day/night operation. In order to increase sensor performance, designers have increased the sensitivity of these cameras. The improvement in camera performance has been dramatic, but because of this increased sensitivity they can be easily saturated by bright light sources like the sun, flashes, etc.

The purpose of this effort is to develop imaging processing software to mitigate these saturation effects and demonstrate performance improvement using a commercially available MWIR camera. Possible image processing approaches might include, but are not limited to, recovering scene content in areas where saturation has not yet been reached or automatically detecting saturation and implementing a real-time response, e.g. changes in integration time.

A variety of metrics have been used to quantify scene saturation. At minimum, percent saturation and average scene contrast should be reported. Other metrics can and should be used as appropriate.

The end goal would be real-time processing of MWIR camera imagery to reduce saturation effects. For Phase I and Phase II goals, demonstrating that image processing techniques can be used to mitigate saturation effects on any time scale is sufficient as long there is a path forward to real-time image processing.

No government furnished equipment will be provided, though representative MWIR camera imagery datasets can be provided upon request.

PHASE I: Demonstrate software that can post-process imagery to mitigate saturation effects representative of those found with MWIR cameras. Measure percent saturation and average scene contrast with and without image processing to quantify improved performance.

PHASE II: Optimize image processing software. Integrate image processing software with a commercial MWIR camera and demonstrate performance with prototype testing in a lab environment. Goals for the prototype include a 50% reduction in percent saturation and/or a 10x improvement in light levels required to obtain saturation. The prototype system (software and camera) shall be delivered to the government for additional testing.

PHASE III: Integrate lessons learned from Phase II into next generation prototype MWIR camera system and demonstrate performance in a lab environment. Explore manufacturability of prototype MWIR camera and modify design to facilitate transition to USAF sensor systems.

REFERENCES:
1. Readout electronics for infrared sensors; J. Vampola; The Infrared & Electro-Optical Systems Handbook. Electro-Optical Components, Volume 3, Chapter 5, 1993.

2. Standardized high-performance 640x512 readout integrated circuit for infrared applications; Naseem Y. Aziz; Robert F. Cannata; Glenn T. Kincaid; Randal J. Hansen; Jeffery L. Heath; William J. Parrish; Susan M. Petronio; James T. Woolaway II; SPIE Proceedings Vol. 3698 Infrared Technology and Applications XXV, 1999, pp.766-777.

KEYWORDS: Mid-Wave Infrared (MWIR) camera, Saturation, Image Processing

AF131-122 TITLE: <u>Modeling and Simulation of Ceramic Matrix Composite (CMC) Processes</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop computational methodology for modeling CMC fabrication processes to accelerate development and facilitate robust and efficient CMC manufacturing processes.

DESCRIPTION: Integrated Computational Materials Science and Engineering (ICMSE) seeks to couple processing, microstructure, and performance via validated computational methods to accelerate materials development, transform the engineering design optimization process, and unify design and manufacturing. CMCs, possessing low density and high-temperature capability, are prime candidates for turbine engine hot-section components and advanced thermal protection systems. In order to be cost-effective alternatives to metal components, the development cycle time for CMCs must be reduced significantly. Modeling and simulation driven optimization of fabrication processes and manufacturing methods can reduce the cost and cycle time to implement CMCs in a variety of aerospace applications. This approach will also reduce the manufacturing trials required to optimize the process for producing specific components. Processes that are used to produce CMCs include one or more of the following, powder-slurry infiltration and densification, preceramic polymer infiltration and pyrolysis, chemical vapor infiltration, and liquid metal infiltration.[1-4] All of these methods rely on the infiltration of the desired matrix phase, or one or more precursors that react to form the desired matrix phase, into a fiber tow or cloth ply or preform architecture. Hence, the processes all rely on flow of gas, liquid, and/or solids though a porous media (fiber network and/or partially densified matrix), diffusion, chemical reactions, and densification, often repeated in multiple cycles, which can lead to residual stresses due to volume and temperature changes. A simulation-based approach will help achieve full densification of parts with minimal defects, dimensional distortions, and residual stress. In addition, silicon carbide-based CMCs require an environmental barrier coating (EBC), applied via plasma spray, physical vapor deposition, or slurry-based methods, to minimize volatilization of silicon hydroxides in combustion environments.[5] Key mechanisms for deposition of coatings to be included in a physics based modeling approach are transport kinetics, chemical reaction mechanisms, densification, volumetric and temperature changes, and residual stress effects. Physics-based computational tools and methodologies are needed to understand these processes, to provide predictive capabilities to model microstructure evolution during processing, and to identify effects of process parameters on microstructure and defect evolution in service. The offeror should conduct a detailed literature search to identify key issues associated with CMC matrix infiltration and/or coating processes. Selection of processes and microstructures to be modeled in Phase I should be representative of those being researched or developed by aircraft and turbine-engine manufacturers; therefore, teaming with a CMC manufacturer or end-user is highly recommended. The potential cost savings and cycle time reductions of the simulation-based approach should be validated in Phase II; one or more CMC components should be identified as test cases. Commercialization plans and qualification requirements should be established to offer these new techniques to the aerospace industry for evaluation and qualification in Phase III. Government Furnished Property (GFP) will not be provided for this topic.

PHASE I: Demonstrate the feasibility of simulating either a commercially-relevant matrix infiltration process for CMCs or an EBC deposition process using a physics-based modeling approach that includes the ability to simulate all relevant physical phenomena. Demonstrate the ability to accurately represent infiltration or deposition and densification for simple geometries.

PHASE II: Fully develop the manufacturing simulation tools developed in Phase I and validate the models and tools on typical CMC components. Working closely with aircraft or turbine engine manufacturers and CMC component manufacturers, demonstrate the cost and/or cycle time reduction claims. Demonstrate predictive capabilities to model microstructure evolution and effects of process parameters on defect populations.

PHASE III: Process models developed should be made available to the turbine engine companies and CMC industry at large. CMCs are applicable to military engine hot-section components. They are also in development for commercial applications such as for power turbines and commercial aircraft engine components.

REFERENCES:
1. W. Krenkel, ed., Ceramic Matrix Composites: Fiber-Reinforced Ceramics and their Applications, Wiley-VCH, Veinheim, Germany, 2008.

2. C.P. Deck, H.E. Khalifa, B. Sammuli, T. Hilsabeck, and C.A. Back, “Fabrication of SiC-SiC Composites for Fuel Cladding in Advanced Reactor Designs,” Prog. Nucl. Energy, 57 38-45 (2012).

3. J.S. Crompton, K.C. Koppenhoefer, S.P. Yushanov, “Simulation of Manufacturing Process of Ceramics Matrix Composites,” Ceram. Trans., Vol. 220, 37-46 (2010).

4. M. Erdal, S.I. Guceri, and S.C. Danforth, "Impregnation Molding of Particle-Filled Preceramic Polymer Infiltration into Fiber Preforms: Process Modeling," J. Am. Ceram. Soc., 82, [8] 2017-2028 (1999).

5. K.N. Lee, D.S. Fox, and N.P. Bansal, “Rare-Earth Silicate Environmental Barrier Coatings for SiC/SiC Composites and Si3N4 Ceramics,” J. Eur. Ceram. Soc., 25 1705–1715 (2005).

KEYWORDS: Ceramic matrix composite, environmental barrier coating, process modeling, process characterization, matrix infiltration, cost cycle time

AF131-123 TITLE: Encapsulation Approaches for Flexible Solar Panels, Displays, and Antennas

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop encapsulation approaches to protect flexible solar panels, displays, and/or conformal antennas from environmental threats with minimal impact on packaged weight.

DESCRIPTION: Flexible electronic devices such as organic light emitting diode (OLED) displays, conformal antennas, and thin film solar panels have the potential to provide revolutionary new capabilities at significantly lower cost. However these materials share a common challenge in their vulnerability to environmental threats. In order to maximize the lifetime of traditional solar panels, the devices are typically encapsulated in glass or in plastics such as Teflon and/or Tedlar, which protect the solar cells and interconnects from weather, dust, and other environmental threats. Although this approach has enabled greater than twenty-year lifetimes for rigid solar cells such as those fabricated from single crystal silicon, this approach is less practical for flexible solar panels. Flexible solar cells, however, could potentially be integrated with personal electronics, clothing, windows, and curved structures. In these cases, encapsulation approaches are needed that maintain the inherent advantages of flexible solar technology – the light weight, thin form factor, and flexibility. In addition, for military applications these encapsulation approaches must provide rugged protection during flexing and survive extreme temperatures.

Flexible electronics and devices have numerous commercial and military applications, including providing auxiliary power to aircraft, air bases, and special operations forces with flexible solar panels. Current state of the art encapsulation approaches for flexible solar cells typically include plastics such as Tedlar or Teflon as well as layers that provide adhesion and handling support. In the packaged solar panel, the photovoltaic layer itself can make up as little as 1-10% of the total thickness and weight. For unmanned aircraft system (UAS) applications, any added weight would reduce the potential flight endurance gains associated with the solar panels. A similar tradeoff analysis would be required for conformal sensors or any aircraft application since weight reduction is a pervasive goal. Some preliminary progress has been made in reducing packaging weight by employing a co-curing scheme involving attaching the solar panels before the composite structural components are treated in an autoclave.

While a co-curing approach has demonstrated limited reductions in packaging weight, a more universal design is needed that would allow for light-weight, durable encapsulation of flexible electronics on UAS or other structures. Encapsulation approaches could include thin polymer film sheets that are attached with adhesives or more innovative solutions such as protective layers deposited by spraying. An ideal encapsulation approach would be compatible with the full range of foreseeable applications (e.g., personal electronics, clothing, windows, and curved structures). For this SBIR project, the encapsulation approach will be demonstrated on a flexible solar panel. Any encapsulation scheme should hermetically seal the solar panels and provide protection from environmental threats such as rain, sand, and mild acids/bases for > 3 years. The encapsulant should be > 80% transparent in the visible-near IR and resistant to UV degradation and scratching. To enable compatibility with organic electronic devices, the encapsulation process should not exceed 130C, and the encapsulant should provide protection to > 150C. The encapsulant should survive the flexing conditions to which these thin film devices are typically subjected (< 1 cm radius of curvature). Evaluation methods should include at a minimum ASTM standards E117-09 (cyclic temperature and humidity), E1830-09 (mechanical integrity), and E1799-08 (visual inspection).

PHASE I: Develop a hermetic encapsulation process for flexible devices that protects them from environmental threats (e.g., chemical, erosion, scratching) while maintaining solar performance characteristics. Demonstrate this process at a scale of at least 1 square inch. The added weight due to the encapsulant/packaging should be less than 200 grams per square meter.

PHASE II: Scale-up the encapsulation process to at least 10” x 10” and demonstrate it on functioning commercially available flexible solar panels. Conduct lifetime testing to demonstrate viability of encapsulation approach. The added weight due to the encapsulant/packaging should be less than 125 grams per square meter. The initial prototype will be evaluated for use on small UAS to extend the flight time.

PHASE III: Potential Air Force applications could include evaluation of the encapsulant on an emerging solar-modified UAS system or on photovoltaic sheets for deployed airbases. Commercial applications could include protection for flexible displays and building-integrated photovoltaics.

REFERENCES:
1. Jason Maung, K.; Hahn, H. T.; Ju, Y. S. Solar Energy 2010, 84, 450-458.

2. Ronald F, G. Composite Structures 2010, 92, 2793-2810.

KEYWORDS: solar, flexible, display, antenna, encapsulation, UAS

AF131-124 TITLE: Methods to rapidly optimize materials for Additive Manufacturing processes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a model-guided experimental method that will determine an optimal set of Additive Manufacturing process control parameters for any given powder sample.

DESCRIPTION: Additive Manufacturing (AM), the set of related techniques that sequentially fuse layers of material to one another in order to build up a part, are rapidly maturing aerospace manufacturing methods whose key strengths are in minimizing the cost, and often more importantly, the time needed to transition from a CAD design to an end-use part. The lack of required tooling, design flexibility, and high part quality are changing the way companies approach the production of low volume or high value parts.

A key challenge that remains to realizing the full potential that AM processes offer is the relatively small number and high cost of feedstock materials suitable for use in additive manufacturing. The cost of the AM optimized powder feedstock is often as much as an order of magnitude higher than the bulk commodity version of the materials, particularly in plastics AM. Due to the high cost and low availability, powder-based AM parts manufacturers are currently dependent on a handful of feedstocks which were often optimized for an entirely different process, such as powder metallurgy or powder coating. The morphology, crystallinity, and size distribution of these powders are rarely optimal for the AM process, and a costly, iterative, and empirical process is required to determine if a new feedstock is even able to produce high-quality parts via AM.

For powders of the same alloy or molecular composition, differences in the shape and size distribution of the powder particles can dramatically change the process control parameters that need to be employed in order to achieve high-quality parts. The selection of appropriate process control parameters becomes even more complicated when fillers and fibers are added to the base powder to improve or modify the bulk material properties delivered in the end use part. For powder bed AM processes such as Electron Beam Melting (EBM), Direct Metal Laser Sintering (DMLS), and Selective Laser Sintering (SLS), excellent powder flow and high packing density are essential when applying fresh powder layers to the powder bed to ensure uniform and consistent part production. For powder feed processes such as Laser Engineered Net Shaping (LENS), stable powder flow ensures that parts are uniformly built.

What is needed are Integrated Computational Materials Engineering (ICME) tools to help rapidly screen new materials by employing model-guided Design of Experiment (DOE) approaches to rapidly find an optimal set of process control parameters for a given AM process. It is anticipated that novel approaches will be needed to create these ICME tools as off-the-shelf continuum fluid dynamics models fail to adequately capture important powder based phenomena such as arching, friction, segregation, stick-slip dynamics, and dilatancy. In particular, it will be essential to model the discrete granular nature of powders and the complex, collective behavior that they exhibit, including densification mechanisms, densification kinetics, and powder-beam interactions.

Beyond the added flexibility of having a larger palette of materials to choose from, and the potential for greatly reduced costs, better understanding of the granular processing properties of powder AM feedstocks will deliver other measurable benefits such as decreasing part porosity, maximizing the recyclability of used powder, and reducing anisotropy introduced due to the layering process that most AM processes employ.

PHASE I: Demonstrate proof-of-concept capability that integrates (metals and/or polymer) powder material properties, as well as shape and size distribution information, into a model that predicts AM processing properties including, but not limited to, powder bed density, powder flow, thermal conductivity, and laser/powder interaction. Particular attention should be given to the validation plan for the model.

PHASE II: The capability developed in Phase I would be extended to include prediction of (metals and/or polymer) powder specific optimal process control parameters for a selected AM process. Demonstrate the capability to improve the processing of a current AM powder feedstock due to variations in feedstock uniformity. This will be based on the developed model or develop an optimized process control parameter set for a powder feedstock that has not been utilized for AM previously.

PHASE III: Technologies should be directly implemented into AM production lines or licensed to AM machine vendors to improve the dimensional accuracy, performance, cost, and quality of production parts and offer a greatly expedited capability for introducing new materials into the appropriate AM process.

REFERENCES:
1. B. Liu et al. “Investigation of the effect of particle size distribution on processing parameters optimization in selective laser melting process” Proc of Solid Freeform Fabrication Symposium (2011) 227-238.

2. R. McVey et al. “Absorption of laser irradiation in a porous powder layer” J Laser Applications 19 (2007) 214-224.

3. A. Simchi “Direct laser sintering of metal powders: Mechanism, kinetics, and microstructural features” Mat Science and Engineering A 428 (2006) 148-158.

KEYWORDS: Additive Manufacturing, Direct Digital Manufacturing, ICME, Integrated Computational Materials Engineering, Powder Flow, Powder Size Distribution

AF131-126 TITLE: Development of Self-Healing Coatings for Corrosion Protection of Repaired Aluminum Components Following Dimensional Restoration

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop/demo coatings for sustained protection of repaired corrosion damaged aluminum components from further surface &/or galvanic coupled corrosion damage [self-healing coatings (SHC)]. App at all maintenance, repair, & overhaul levels of repair.

DESCRIPTION: Solutions are being developed to reliably identify apparent and hidden corrosion on aluminum surfaces and components, clean corroded areas without leaving undesirable residues, and restore lost substrate material. Many products have been developed in academia and industry. Current status quo materials usually only perform one topic activity such as remove corrosion or SHC system. This topic will combine all of these activities instead of having to develop each concept from the beginning. This topic addresses the need to identify, qualify, and certify post-repair corrosion-inhibiting SHCs with self-mending properties in order to inhibit further corrosion. The

SHC product must meet MIL-PRF-85285 and/or MIL-PFR-32239 for performance and environmental issues. Product application shall follow the parameters identified in general series technical order 1-1-8. Product is desired to have lower volatile organic compound levels and hazardous waste components than the current Mil Spec requirements. These Mil Specs will identify the basis for research conditions, testing, and evaluation. Product is desired to perform on aircraft materials such as aerospace aluminum alloys, titanium, and composites. It is critical to involve Depot and Air Force customers to address potential issues, i.e., production modifications and realignment requirements. Coating materials and application methods for sustained self-mending of corrosion on war-fighting systems must be quick, transportable, field deployable, financially viable, and reliable.

PHASE I: Research post-repair corrosion coating materials application methods and equipment to accomplish long-term resistance to corrosion and self-mending limited damage. Demonstrate feasibility of approach with coupon testing. Conduct Technology Working Group involving industry, academia, and government agencies to review findings/recommend technically feasible solutions.

PHASE II: Perform further concept refinement and process optimization, assisted with subscale prototypes. Design algorithms and test protocols to qualify SHCs for components and subsystems of representative geometries.

PHASE III: Fully develop, qualify, and certify self-healing anti-corrosion material, process, and equipment in DoD. Collaborate with depot structural and material engineers to apply technology for components. Coordinate with Commands to develop applications applicable for operating bases for multi-service use.

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KEYWORDS: Corrosion, materials design, self healing coatings (SHC), self-mending, cost reduction

AF131-128 TITLE: Development of an Onboard Video Processing Platform for Small Unmanned Aerial Systems (SUAS)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop an on-board video processing platform for SUAS that achieves a significant decrease in SWAP requirements without compromising performance and ease of programmability.

DESCRIPTION: Recent improvements in imagery devices--both infrared (IR) and visible (EO cameras--have led to a significant increase in the number of pixels that can be captured per second in a SWAP-constrained environment. For example, it is now possible to capture over 70 megapixels (MP) per second (MP/s) in a camera that can fit in a 6-foot wingspan UAS. These dramatic improvements in captured MP/s, however, introduce a new problem: how to utilize the pixels that are generated by these cameras.

Traditionally, small UAVs would capture a television-type video (approximately 9 MP/s), compress, and transmit this video back to the ground for exploitation. With an increase in Pixels captured per second, however, compression becomes far more difficult in the SWAP constraints of a SUAS.

One alternative would be to detect the "interesting" portions of the captured imagery and send only that information down. However, this requires significant exploitation of the imagery to occur onboard the SUAS. In either case (increased compression or exploitation), significant increases in the computational capabilities of onboard processors are required in SWAP-constrained environment.

In addition to the need for more computation onboard SUAS, this computation cannot come at the expense of the ease of programmability. Because these high-pixel count imagery sensors are relatively new, the exploitation algorithms for this imagery are still being developed. Therefore, creating a specialized computational platform (such as a field-programmable gate array (FPGA) or application specific integrated circuits (ASIC)) for performing exploitation onboard SUAS is not practical. Instead, the desired computational platform must meet stringent SWAP constraints while being easy to develop for (e.g., the Intel x86 platforms) and re-program.

Of particular interest is the recent development of high-performance processors for the cellular phone industry. Cell phones now have the ability to compress HD video in real-time, perform other processing on collected imagery, and perform significant 3-D graphics computations. In addition, these computationally intensive applications have been enabled in an extremely limited SWAP environment.

Therefore, this topic is an attempt to solve the current imagery processing problem with SUAS by leveraging COTS processors for performing video processing onboard. Current SUAS typically use PC104-type computation platforms to interface with cameras onboard. However, the SWAP constraints of these computation platforms limit the ability of SUAS to collect and transmit video data.

On the other hand, the advertised SWAP capabilities of cell-phone processors are almost an order of magnitude better than current PC104-based platforms. Therefore, this project should create a platform, utilizing a cell-phone processor, for capturing, processing, and compressing video onboard a SUAS at a greatly reduced SWAP cost.

Commercialization potential: There are numerous defense and civilian applications that could benefit from a development of this type of processor. Defense applications include all micro, mini, and small UAS currently used for collecting EO/IR imagery. Civilian applications include many embedded aerial and ground robotics applications where video processing is required to complete tasks.

PHASE I: Search for/compare and purchase available mobile video processors. Work w/govt. to choose set of image processing algorithms as benchmark for set of possible processors. Evaluate each processor on video processing performance, ease of programmability, ability to interface with different units (including cameras, inertial measurement units (IMUs) and wireless comm. devices) and SWAP requirements.

PHASE II: Develop a computational platform capable of executing a large set of video processing algorithms with minimal algorithm development time and within the SWAP constraints of a SUAS. Develop a software library of multiple video processing algorithms that efficiently execute on the designed platform. Source code delivery to the government is required. Demonstration of the computational unit in a SUAS during government-run flight tests will be performed.

PHASE III: In this phase, refinement of the computational unit for inclusion with a specific targeted SUAS platform will be performed. Testing of the unit's performance in a variety of operating conditions will be required.

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KEYWORDS: On-board Vision Processing, Video Compression, small UAVs

AF131-129 TITLE: Non-Mechanically Steered 3D Imaging LADAR

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop and demonstrate revolutionary technologies for high speed non-mechanical steering of 3D imaging Laser Detection and Ranging (LADAR) sensors for target acquisition, identification, and tracking.

DESCRIPTION: A novel approach is needed to bridge the gap between the 3D LADAR focal plane array (FPA) size and the area coverage rates and resolution required by tactical targeting systems. Instantaneous 3D LADAR imagery is currently limited by FPA size and the laser power required to illuminate the region of interest. (ROI) One possible new approach is to use mosaic imaging, where narrow field of view (FOV) 3D images can be tiled to provide high resolution composite images and increased FOV. The conventional approach to perform mosaic imaging would use fast steering mirrors (FSM), however, this increases SWaP, increases the complexity of the optical train, reduces reliability, and is ultimately limited in speed by the mechanical assemblies. Non-mechanical (or micro-mechanical) steering systems are ideal candidates for providing the tiling capabilities at high speeds with low SWaP and could be installed in the gimbal system of a pod or a Unmanned Aerial Vehicle (UAV) to allow the existing designators and imagers to operate while providing off-boresight situational awareness and tracking capability for multiple target engagements. Non-mechanical beam steering (NMBS)devices can provide true random access, enabling selective scanning of a FOV for structured targets, potentially reducing the data transmitted for ISR type missions.

The goal of the system is to integrate a 3D LADAR with a NMBS device in order to improve the 3D imaging area rate and FOV.

The LADAR should provide a cross range and depth resolution of 15 cm voxels (VOlume piXELS) and an effective range in excess of 10 km. The steering system must provide both steering for the illuminator laser and the detector, though not necessarily through the same aperture. 3D LADAR are broadly classified into two categories. First, a scanned approach where small arrays of detectors are flood filled with laser energy and then scanned to provide a build up to a larger image. This requires relatively low peak pulse power, but high pulse repetition frequencies approaching 50 kHz. Second, are flash systems where the image is acquired using a single high energy, designator class pulse, in the MW/cm^2 range for ns pulses. Flash imagers may also be scanned to build up larger images, but at lower rates. Mosaic imaging is common to both designs and must minimally construct an overall FOV of 1 to 5 degrees, which is similar to that of a targeting pod Forward Looking Infra-Red (FLIR) camera. The 3D LADAR imaging system must also attain update rate of 30 Hz over the entire FOV. This corresponds to a steering rate of N*30Hz, where N is the number of tiles in the mosaic. The sensor system should operate at the short wave infrared (SWIR) wavelengths (nominally 1.5 microns). A UAV or pod has limited space and shared apertures are advantageous. The primary aperture is typically a mid wave infrared (MWIR) FLIR and transparency at 3-5 microns would allow placement of NMBS device at the front of the FLIR aperture. NMBS elements could also be placed behind the FLIR optics.

PHASE I: In this initial phase; concepts will be developed, evaluated, and computer modeled. Design challenges and trade-offs will be tabulated and areas in need of additional research and development will be identified. A concept design will be developed and provide an integration pathway to aircraft.

PHASE II: A bread board prototype sensor package will be built which demonstrates non-mechanical 3D LADAR mosaic imaging over at 5x5 degree FOV with the steering rates and resolutions in accordance with the Phase I design.

PHASE III: The bread board prototype will be redesigned to fit in the SWaP constraints of a tactical pod. The system will be flown and evaluated.

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KEYWORDS: optical phased array, 3D LADAR, flash imaging, non-mechanical, beam steering, image steering, mosaic, mosaic imaging, tiled, tiled imaging

AF131-130 TITLE: New Radar Exploitation Methods for Combat Identification

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop automatic target recognition capabilities based on reduced feature sets (i.e. salient feature representation to reduce dimensionality and enhance performance) to support on-board combat ID and decision fusion for remotely piloted vehicles.

DESCRIPTION: Emerging operational requirements using remotely piloted vehicles (RPV) for combat identification (ID) demand highly accurate, efficient multi-sensor automatic target recognition (ATR) systems. Conventional systems either provide on-board image-only information or ground station exploited-imagery information. Yet, reduced size, weight and power requirements of advanced computational systems combined with efficient methods and algorithms suggest opportunity to develop image and exploitation products directly on board the RPV. Rather than generate imagery and then exploit the image, novel approaches could perform feature extraction and exploitation jointly with imaging to provide enhanced ATR performance.

This effort addresses the potential to enhance ATR performance through novel exploitation of high resolution radar (HRR) and synthetic aperture radar (SAR) data derived from common tactical radar systems that do not have full polarimetric capabilities. The primary applications are tracking and targeting of moving and stationary military and civilian ground vehicles using active, monostatic air to ground radars. Technical challenges to produce this type of multi-sensor ATR include real-time image formation and feature extraction/exploitation along with fast, efficient algorithms. Recent advances offer new approaches to performing joint image/feature extraction for ATR [1-2]. Integration of the image formation process with feature extraction to accomplish ATR could be advantageous in maintaining pedigrees needed to achieve high confidence and accuracy in the fused solution. One possible approach is the use of attributed imagery [3], in which each qualifying pixel is attributed during image formation as a canonical or primitive structure referred to as an attributed feature. Besides contextual information from the image, the attribution offers potential to convey additional information for increased confidence and accuracy in classification. This approach, applicable to both SAR and HRR data, could be used to form a joint ATR with compact feature space that operates on physics-modeling rather than stochastic modeling.

This work will explore the feasibility for using compact feature target representation along with novel ATR and fusion algorithms to develop on-board combat ID capabilities. The effort should include the use of attributed features or other data constructs optimized to convey covariance, invariant feature data [4,5] or other information necessary to support the development of an efficient, high confidence ATR. The proposed concepts should function to the highest possible degree with data extracted from existing target data sets. ATR development must include metrics for measuring and validating performance (e.g. efficiency, speed, and accuracy) throughout the decision chain.

Proposers must be familiar with target modeling, feature extraction and data fusion techniques used in ATR and have at least 3 years experience in the development of ATR algorithms for both HRR and SAR. A limited data set will be made available to successful Phase I proposers and no other government materials, equipment, data, or facilities will be provided under Phase I.

PHASE I: Develop concepts for extracting and representing salient, compact feature sets from SAR and HRR data with potential to improve ATR performance. Develop ATR algorithm and data fusion concepts based on compact feature sets. Develop mathematical uncertainty models for feature extraction and propose metrics for tracing performance and uncertainty throughout the ATR classification process.

PHASE II: Develop and demonstrate ATR object classification algorithms. Develop and validate uncertainty models and metrics for the ATR system from end to end (i.e. feature extraction to decision declaration). Develop concepts and requirements for on-board ATR capabilities supporting high confidence combat ID. Demonstrate and validate the ATR system performance using existing data sets.

PHASE III: Military Application: Provide automated object discrimination and classification for targeting, target exploitation and situational awareness. Commercial Application: Provide automated object discrimination and classification for land and ocean rescue operations.

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KEYWORDS: automatic target recognition, ATR, feature extraction, attributed imagery

AF131-131 TITLE: Group 4-5 UAS integration of terminal area sensors & operations in the terminal area for Airborne Sense and Avoid

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop technology to utilize and integrate terminal area ground based sensors for sense and avoid operation of a UAS in a terminal area.

DESCRIPTION: Terminal Area Operations are intended to facilitate UAS operations in a confined volume of airspace near a regional terminal area or near a restricted airspace. To ensure safe UAS operations in the terminal environment, one concept utilizes ground-based observers or sensor technology capable of scanning beyond the edges of the confined operational airspace volume. The observers or sensors alert the UAS pilot/operator of approaching traffic so actions may be taken to avoid potential collisions with other traffic. Alone or in conjunction with participating air traffic controller (ATC), UAS must effectively conduct their training and other missions without impacting the safety of other manned aircraft and the controller's workload.

Terminal area UAS operations are conducted in a volume of airspace associated with an operating airfield, and may be conducted in Class C, D, G, or E airspace. Three phases of flight are associated with terminal area operations: departure, rectangular/overhead pattern work, and arrival/landing. For Group 4-5 UAS, terminal area operations require a runway environment for takeoffs and landings. The terminal area can be a complex and challenging environment. Through continual monitoring of air traffic (cooperative and non-cooperative) and the appropriate separation/collision avoidance procedures, SAA technologies provide enhanced safety of flight for both manned and unmanned systems.

DoD UAS pilots/operators will apply the appropriate separation minima when transiting through a terminal area to ensure safe separation/collision avoidance. UA separation criteria will be no less than the appropriate separation minima as defined in FAA JO 7110.65. If avoidance action is required, pilot/operator will make an immediate collision avoidance maneuver and relay deviation to the appropriate controlling agency. Once the UA is clear of the conflict, the pilot/operator will notify/coordinate with the controlling agency and continue normal operations. Both vertical and lateral maneuvers may be accomplished to avoid traffic. In order to maintain safe separation, air traffic must be appropriately tracked as specified in the Department of Defense Unmanned Aircraft System Airspace Integration Plan (see references).

Many types of sensors are being evaluated for Airborne Based Sense And Avoid (ABSAA) and Ground Based Sense And Avoid (GBSAA). The ABSAA consists of ownship EO and Radar sensors along with detection and tracking capabilities under development. The GBSAA consists of typical ATC radar systems that will provide track data. While moving into a terminal area, the number of intruders will likely be increasing and the distance between these intruders and the ownship will be decreasing, resulting in a higher risk environment. There are other challenges for false alarms generated by the ABSAA EO component such as moving objects and other ground clutter due to EO phenomenology.

Similarly, the ABSAA radar system does not provide a perfect air picture under all operating conditions.
The primary objective of this effort is to demonstrate a significant improvement in tracking of airborne traffic through the fusion of the ABSAA and GBSAA systems as compared to the capability of the individual systems. Capabilities of the ongoing development of the ABSAA systems, specifically the EO and Radar sensor and tracking capabilities will be provided as Government Furnished Data. Similarly, typical GBSAA performance characteristics will be provided. At a minimum, true target track and false alarm characteristics will be provided to enable modeling of existing capabilities.

PHASE I: Identify proposed solutions to utilize the combination of the Ground Based Sense And Avoid (GBSAA) system with Air Borne Sense And Avoid (ABSAA) track data for use by a UAS in terminal areas. Establish feasibility of proposed solutions through simulation, analysis, and appropriate scientific means. Quantify the performance against operating conditions (i.e., air space density).

PHASE II: Refine the most promising Phase I solution(s) towards an operationally relevant implementation involving the use of real versus simulated government furnished data. Identify and potentially resolve critical issues for fielding new fused solutions integrating ground and airborne sensors.

PHASE III: Develop Phase 2 solution(s) to be compatible with current or planned military and commercial collision avoidance systems. Implement a product capable of integration with at least one current UAS.

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2. Joint Concept of Operations for Unmanned Aircraft Systems Airspace Integration, May 2011.

3. Department of Defense Terminal Area Airspace Access Profile Recommended Practices Guide, Version 0.5, 23 March 12.

KEYWORDS: Unmanned Aerial System, Terminal Area, Collision Avoidance, Sense and Avoid, Airborne Separation, Airborne Maneuver, Traffic Alert, GBSAA, ABSAA

AF131-132 TITLE: Real-Time Sensor Data Processing and Compression Performed On-board Unmanned Aerial Systems (UAS)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop onboard sensor processing capability for electro-optical (EO) and/or Infrared (IR) data that can support real-time identification, tracking, and selection of regions of interest (ROIs) based on environment, target sets and mission priorities.

DESCRIPTION: The purpose of this research project is to develop practical concepts for effective, adaptive processing architectures and real-time processors that allow identification and selection of ROIs based on environmental conditions, user mission priorities, and collateral data sources similar to the saliency process the human brain uses to identify ROIs. Annotation and extraction of the ROI data in real-time, preliminary classification/ recognition of ROI data content, and reduced bandwidth requirements for critical data transmission to the ground system, are the primary objectives of this research. Performance metrics include accurate determination of ROIs, annotation of data streams, and selection of windows of data for transmission at a pixel input rate of 10E9, processing latency of less than 2 seconds, and power expenditure for processor operation of less that <150 watts when operating at a rate of 20 teraops with a maximum processor weight of < 5 kilograms. Advances in military sensor technologies, especially in the area of focal plane arrays, has resulted in an increased potential for significantly improved resolution and area search rate. Improvements in resolution allows detection, tracking and persistent observation of dismount activities that are difficult without lower resolutions. The new wide-field of view (WFOV) high-resolution persistent surveillance video sensors have increased the amount of data by several orders of magnitude. These very large increases in sensor data are overwhelming the bandwidth capacities of Unmanned Aircraft Systems (UAS) to transmit the data and are overloading the capabilities of analyst teams to support timely assessment and interpretation. Additionally, the user needs a corresponding capability that will assist imagery analysts to exploit this new data real-time. DoD Task Forces have estimated that future assets in Theater will provide a 5000X increase in the already unmanageable amount of sensor data produced. Data loads being produced by development systems, such as the DARPA developed Autonomous Real-Time Ground Ubiquitous Surveillance Imaging System (ARGUS-IS) system, approach that of the human vision system which sends up to 72 Gigabytes of information per second to the brain! Saliency is the perceptual quality which makes some items in the world stand out from their neighbors and immediately grab our attention. The human visual system receives and processes the eye's wide field of view images and determines regions that require "attention". This "saliency" processing uses size, shape, texture, motion, and color to determine regions of interest. The eye uses the high definition fovea in the center of vision to examine the ROI. This high resolution data is processed for recognition and interpretation in the visual cortex.

PHASE I: Develop an architecture which demonstrates the saliency and classification/recognition functions emulating the processes of the human brain. Design a processor incorporating innovative processing elements upon which the processing architecture can be instantiated. ISR data containing detectable dismounts shall be processed and Pd, Pfa shall be estimated from processing in an emulation environment.

PHASE II: Phase I sensor processing architectural concept and designs shall be incorporated into a more detailed processor design and performance demonstrated. The emulation environment shall be modified to represent the processor. Processor performance shall be estimated across the spectrum of conditions. An Engineering Development Plan shall be developed.

PHASE III: Military applications include unmanned vehicles including aircraft, ships, and tactical land vehicles. Missions in the civil and commercial markets include physical security for border, maritime, and port surveillance applications, search and rescue and natural man-caused disaster support.

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KEYWORDS: Video Analytics, Electro-Optical Sensors, Infrared Sensors, On-board Processors, UAS, real-time processing, targets, tracking, regions-of-interest (ROIs), imagery

AF131-133 TITLE: Long-distance 3-D Reconstruction from EO/IR Imagery

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To combine machine learning-based single image three-dimensional (3-D) reconstruction techniques with current multiple image techniques, enabling long-distance, low-angular diversity 3-D reconstruction.

DESCRIPTION: Recently, significant gains have been made in the capability to generate 3-D models of an area from aerial electro-optical or infrared (EO/IR) imagery. The ability to create a 3-D model of the observed area is beneficial for many downstream image exploitation applications. For example, change detection, target tracking, and geo-registration all benefit from the information contained in a accurate 3-D model of the area being observed. In addition, a 3-D reconstruction of an area of interest can help the warfighter to quickly obtain an understanding about that area.

While current techniques for 3-D reconstruction from EO/IR imagery are starting to yield high-quality 3-D models, the algorithms used to implement these techniques require significant angular diversity between the imagery. In other words, accuracy of the model is dependent on collecting imagery from multiple viewpoints of a single object, with large differences in viewing angle present among the set of viewpoints. This requires a flight pattern that enables the aircraft collecting the data to observe the area for an extended period of time, from multiple viewpoints. This type of flight pattern is not feasible in many scenarios, requiring a modified approach to 3-D reconstruction.

In addition to angular diversity-based 3-D reconstruction approaches, algorithms have been introduced in the research literature that utilize machine learning techniques to perform 3-D reconstruction from single images (e.g., see references below). These techniques, however, generally ignore the possibility of multiple images of an object. The Air Force seeks techniques that merge both multiple image (angular diversity) and single image reconstruction techniques to enable long-distance 3-D reconstruction of an area. In long-distance reconnaissance scenarios, there will not be enough angular diversity between collected images to enable high-accuracy multiple image reconstruction techniques in isolation. However, improved accuracy over single-image reconstruction techniques should be possible with multiple images collected of the same area with some small amount of angular diversity.

Techniques that optimally fuse both single and multiple image 3-D reconstruction methodologies are the focus of this work. Data from an aerial platform collecting imagery of 3-D objects at long range will be the target input for this work.

Commercialization potential: Approaches developed under this project could be used in the processing chain of any military surveillance asset. In addition, non-defense related applications include the automated mapping of urban areas (e.g., for Google or Bing maps), civil surveying, and the automated creation of virtual environments.

PHASE I: In Phase I, the contractor will demonstrate 3-D reconstruction algorithms on a government-provided data set with views differing by less than 90 degrees. Improved performance will be demonstrated by combining single and multiple image reconstruction techniques. An accuracy comparison between reconstruction approaches at various distances from the target will be delivered.

PHASE II: The contractor will expand the operating conditions under which accurate 3-D reconstruction can occur, including more limited angular diversity, different types of terrain, and allowing limited human intervention to quickly reconstruct large areas. Fusion with external inputs (e.g., Global Positioning Satellites (GPS), inertial measurement units (IMUs), geo-referenced satellite imagery) may also be enabled. Demonstrations using both EO and IR imagery will be performed.

PHASE III: This technology will support the warfighter in quickly obtaining an understanding of areas that are observed by long-distance aerial platforms. Phase III will be used to take the technology developed and create a product that is robust and reliable enough for use in real-world scenarios.

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KEYWORDS: 3-D reconstruction, Machine Learning, Image Exploitation

AF131-135 TITLE: <u>Fully Adaptive Radar</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop closed-loop radar operation concepts and analyze performance of optimal and adaptive radar from a single and distributed sensing perspective.

DESCRIPTION: The concept of fully adaptive radar (FAR) seeks to exploit all available degrees-of-freedom on transmit and receive in order to maximize target detection performance. This area has received increased interest in recent times and builds upon a rich history outlined in the references and citations therein. Of key importance is the concept of closed loop radar operation via feedback from the receiver to transmitter for guiding the next illumination. This enables enhanced adaptive target detection, in computationally demanding and training data starved scenarios. The most significant Air Force benefit afforded by FAR is the ubiquitous ability of the radar to adapt to its environment as opposed to pointing the radar in a given direction and interrogating for presence of targets. Specifically, FAR offers the potential for 2X to 10X performance over state-of-the-art in terms of output signal-to-noise-ratio (SNR), and error variance in parameter estimation. This translates to a 3-10 dB improvement in target detection performance over the state-of-the-art.

Closed loop radar operation is replete with open problems spanning a broad gamut of research areas-detection, tracking, and classification from single as well as a multi-sensor perspectives. The focus of this effort is the radar target detection problem in environments with unknown spectral properties.

Estimating the unknown spectral properties has been the focus of a large body of research spanning 5 decades. The underlying challenges in this context are documented in the references and citations therein. Two important issues that arise in the context of FAR for adaptive target detection include (i) Deriving the performance limit (optimal performance) afforded by FAR? (ii) Developing the criteria for adaptive processor performance to lie within a prescribed level of the optimal. A principled investigation of these issues includes the following items.

A first step is the development of the feedback signal from the receiver to the transmitter via prescribed metrics such as mean squared error, entropy, or mutual information. The next step is to develop analytical as well as computer simulation methods for determining the false alarm and detection probability for the optimal processor with respect to single and multiple radar waveforms. Furthermore, due the large number of degrees of freedom, the number of unknown nuisance parameters incurs a substantial increase. Since these parameters need to be estimated from training data, the amount of training data needed to attain adaptive performance within 3 dB of the optimal processor is required.

Performance analysis and validation of the adaptive technique with respect to the training data support, false alarm probability, robustness of detection performance to parameter mismatch, and computational cost is sought. Extension of this approach to handle distributed and multiple input/multiple output (MIMO) radar performance must be undertaken. Performance validation for both single and distributed radar needs to be analyzed using simulated and measured data sets. Accordingly a three phase campaign as outlined below is in order.

PHASE I:  Develop criteria for characterizing feedback from the receiver to transmitter. Analyze optimal closed loop radar processor detection probability performance for a fixed false alarm probability. Develop and analyze adaptive processor performance using simulated data. Key considerations are training data support and computational cost. Metrics include output SNR and error variance in parameter estimation to quantify target detection performance improvement over the state-of-the-art.

PHASE II:  Techniques developed in Phase I will be extended to MIMO radar and distributed radar configurations employing fixed and varying waveforms. A key challenge in this regard is the dependence of the training data on the geometry of the MIMO/distributed radar configuration. Compensation techniques for training data heterogeneity are needed. Adaptive processor performance must be extensively analyzed with simulated and measured data. The same metrics as in Phase I will be used to quantify performance improvement over the state-of-the-art.

PHASE III:  Transition opportunities for this effort include RLSTAP and RAST-W upgrades within AFRL, ongoing MIMO radar programs at ESC/EN as well as JSTARS and AWACS. Commercial applications include law-enforcement and toxic waste site detection using distributed sensors.

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KEYWORDS: fully adaptive radar, radar waveform, optimal and adaptive signal processing, training data support, computational cost

AF131-136 TITLE: Manpack antenna for Advanced MIL SATCOM

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a light weight auto-tracking antenna for manpack satellite communication terminal. The terminal will provide the AJ and LPD communications capability to dismounted forces (TACP and SOF) and will operate at AEHF frequencies.

DESCRIPTION: The Advanced Extremely High Frequency (AEHF) satellite communictions system provides global, secure, protected, and jam-resistant communications for high-priority military land, air, and naval warfare. Our dismounted forces Tactical Air Control Party (TACP) and Special Operation Forces (SOF) have a great need for an anti-jam (AJ) and low probability of detection (LPD) satellite communication terminal. Since the troops already carry over 100 lbs of gear it is extremely important that the terminal and antenna weigh less than 16 lbs including the battery. The required duty cycle is 10-1-1 where ten hours is idle/standby, one hour receive and one hour transmit. To maintain the satellite link the antenna must track the satellite. The beam pointing doesn't have to be continuous but it needs to be re-pointed every 15 minutes at a minimum. More active tracking or continuous tracking may allow for higher data rates or the ability to acquire/maintain links in adverse conditions (rain, low look angles). While this can be done manually it is preferred to track the satellite automatically to minimize already task-saturated operator involvement. The AEHF manpack terminal with its small lightweight auto-tracking antenna should be able to close the link in clear weather at 256 kbps data rate. The antenna must be sized to fit within the overall terminal size, weight, and power limits. In addition, it cannot consume more power than the overall system can supply with 10-1-1 duty cycle. Other relevant antenna parameters are: VSWR 2:1, gain 39.0 dBi, pointing loss 1 dB, and polarization loss 0.2 dB.

The overall goal of this effort is to design, then build and demonstrate a 44 GHz transmit and 20 GHz receive antenna that weighs less than 10 lbs and consumes less than 20 W in operation. The antenna must be able to close and maintain a 256 kbps link in AEHF band. A small hard reflector antenna (12 inch or less) or a larger foldable reflector are both acceptable to the user. Other solutions and new innovative antenna concepts are encouraged to be explored while keeping in mind efficiency, size, weight and power.

PHASE I: Perform a design study for an AEHF auto-tracking antenna that weighs less than 10 lbs and consumes less than 20 W in operation. The operating frequencies are 44 GHz transmit and 20 GHz receive and the antenna must be able to close and maintain the link at a 256 kbps data rate.

PHASE II: Based on Phase I study, refine the design and prototype and demonstrate the antenna. Testing can be done by connecting the antenna to an existing, government furnished radio, i.e., Milstar Command Post terminal, and tracking an AEHF satellite for two hours. The receiver noise figure is 3 dB. The AEHF terminal is located at MITRE Bedford Lab, and it's owned by the AFLMC/HNA.

PHASE III: The auto-track system could apply directly to commercial portable antenna systems for emerging commercial Ka satellite services. Accurate tracking could improve data throughput in comparison to existing systems.

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2. Advanced Wideband Terminals ORD AWT ORD CAF-AMC-AFSOC 002-95-III-C, Mar 2004.

3. ACC TACS Functional Concept, September 2008.

4. AFSOC FY12-37 Master Plan, dated 1 Sep 2009.

5. Battlefield Airmen Operations (BAO) Human Machine Interface (HMI) CDD, 9 Jan 2007.

6. CPD for the United States Special Operations Command (USSOCOM) SOF Next Generation Tactical Communications Capability (NGTCC) System, dated 1 April 2007.

7. Enabling Concept for Airborne Wideband Communications, 23 June 09, Air Combat Command (ACC).

KEYWORDS: AEHF terminal, portable AEHF antenna, manpack antenna, Advanced MIL SATCOM

AF131-137 TITLE: <u>Very Low Frequency Receiver front end with high sensitivity and frequency selectivity</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Demonstrate new VLF receiver front end for NC3 airborne missions. The technology requires high sensitivity for distance reception of weak signals in the 14kHz to 60kHz range and high selectivity to discern a signal of interest from crowded VLF band.

DESCRIPTION: Current airborne VLF receiver technology for Emergency Action Message (EAM) reception must meet stringent reception capabilities in harsh environments. Receivers were designed in the 1970s and 1980s to accomplish this task in certain environments, against certain threats. Since that time, USAF VLF transmitters have significantly decreased, providing a much weaker signal for VLF receivers to copy. Furthermore, the threat to Nuclear Command Control and Communication (NC3) has arguably become more adaptable and global, demanding that USAF EAM reception become more adaptable and global in response. Relying on Navy VLF Transmitters dispersed around the world could pick up the slack, but current USAF VLF receivers cannot tune to them. A new front end (that part of the VLF receiver between the antenna and demodulator) designed to copy both USAF and USN transmissions could address some of these problems, but this feature would add new problems of additional signals from transmitters occupying dense space in frequency. This topic targets a front end technology that would require high sensitivity to copy messages at distance and fine selectivity to tune to a specific transmitter whose frequency may be very close to that of another transmitter. In addition to these challenges, VLF receiver technology is expected to perform under the excessive noise of jamming sources and nuclear scintillated atmosphere (post Nuclear or high EM pulse event). Compounding these obstacles to robust VLF reception in currently fielded equipment are obsolete technology, poor logistics and sustainment management, strict funding lines, and a decimated VLF industry base and expertise. The VLF Receiver front end must surpass state-of-the-art receiver specs (see reference). A full VLF receiver design that meets these capabilities may lie outside of the duration and funding scope this research project and so the front end was chosen as a suitably scoped topic. The front end alone will not be enough to solve USAF survivable VLF reception issues, but a modular front end technology developed through SBIR could be integrated with other receiver subsystems in the future for full functionality. The research and demonstration of this front end technology is independent of the three other VLF topic submissions (Flight line VLF transmitter, militarized VLF antenna, hardened Human Machine Interface for VLF receiver).

PHASE I: Develop an architecture for a VLF receiver front end with high sensitivity (<0.325uV) and selectivity (filter with >60dB out-of-band-rejection). Determine which components are COTS available, and which require further development. Identify critical components and perform RF compatibility modeling. The front end design must consider airborne NC3 mission requirements (Jammer & Noise rejection).

PHASE II: Design, build and test VLF receiver front end and demonstrate performance in a simulated stressed channel (airborne, jamming, long distance, atmospheric scintillation). Develop packaging requirements and interface control document to ensure flight worthiness.

PHASE III: Integrate VLF front end with operational VLF receive system for flight demonstration.

REFERENCES:

1. Cohen, M.B.; Inan, U.S.; Paschal, E.W.; "Sensitive Broadband ELF/VLF Radio Reception With the AWESOME Instrument," Geoscience and Remote Sensing, IEEE Transactions on, vol. 48, no.1, pp.3-17, Jan. 2010.

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3. Morton, T.; Sickles, K.; "The Role of Propagation Effects in Airborne RF Communication Systems Design," Aerospace and Electronics Conference, 2008. NAECON 2008. IEEE National, pp.78-84, 16-18 July 2008.

4. THALES VLF/LF digital multichannel receiver (TRC-2556); http://www.thalesgroup.com/Portfolio/Defence/Defence_Products_VLFLF_TRC_2556_Receiver/.

KEYWORDS: VLF, NC3, airborne, EAM

AF131-138 TITLE: Lightweight AEHF Modem for Manpack

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a lightweight, low power, AEHF modem. This would be used for a terminal that can provide AJ and LPD communications capabilities for dismounted forces (Air Control Party (TACP) and Special Operations Forces (SOF)).

DESCRIPTION: A terminal that can provide AJ and LPD communications capabilities for dismounted forces (TACP and SOF) is a serious technical challenge. These dismounted troops typically carry over 100lbs of gear and cannot accept more weight than they already carry. These dismounted forces need data rates in the 100’s of kbps using equipment that is less than 16 lbs including the battery. They typically operate on a 10-1-1 duty cycle where 10 hours is idle/standby, 1 hour receive and 1 hour transmit. A small lightweight, low power modem that can operate on the AEHF satellite in clear weather at 256kbps is a serious technical challenge. AEHF is a complex, high speed, interleaved, spread spectrum, frequency hopped system. Creating a modem with the requisite processing speed while simultaneously meeting the size, weight, and power constraints of a man pack terminal is required.

The AEHF capable modem must weighs less than 0.1lbs and consumes less than 1.1W in operation. In addition, it cannot consume so much power that the overall system cannot meet the 10-1-1 duty cycle. The modem should support the following modulation types: Frequency Shift Keying (FSK), Filtered Symmetric Differential Phase-Shift Keying (FSDPSK), Gaussian Minimum Shift Keying (GMSK), and PGMSK. It should support rate ½ encoding, symbol repeat, time permute, frequency permute, and data interleaving/deinterleaving. The modem should support a channel bandwidth of at least 20 MHz. The government can provide additional implementation details upon contract award.

The overall goal of this effort is to design, then build and demonstrate an AEHF modem that meets the size, weight and power goals. The demonstration will be conducted with a satellite simulator.

PHASE I: Conduct a design study for an AEHF capable modem that weighs less than 0.1lbs and consumes less than 1.1W in operation. Modem must be capable of operating in all AEHF modes.

PHASE II: Prototype and demonstrate an AEHF capable modem that meets the size, weight and power requirements. This demonstration will be conducted over an AEHF satellite simulator.

PHASE III: While direct application of an AEHF modem has little commercial value, the technology and ability to create a very small and efficient high capacity modem is applicable to the emerging commercial Ka SATCOM community.

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2. Mortazavi, M.; Fizell, W.; , "Bandwidth efficient channel spacing for on board processing satellite communications-simulation results," MILCOM 2000.

3. 21st Century Military Communications Conference Proceedings , vol.2, no., pp.1099-1103 vol.2, 2000.

KEYWORDS: modem, AEHF, terminal

AF131-139 TITLE: GMTI Data Exploitation For SWAP Limited Radar Systems

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop advanced ground moving target indicator (GMTI) signal processing algorithms for use on airborne SWAP (size, weight and power) limited radar systems, for improved capability to detect, geo-locate, and characterize moving targets on the ground.

DESCRIPTION: Ground surveillance radar is an established component of the DoD’s battlefield awareness strategy, providing persistent surveillance during day or night, and during all-weather conditions. Advanced radar systems are capable of suppressing stationary clutter in order to detect and characterize slowly moving and low observable targets, as well as providing estimates of target locations in range and cross-range.

The use of tier II unmanned air vehicles (UAV) is increasing for both the military and homeland security. They are assuming roles of combat, intelligence and reconnaissance. However, the payloads of these aircraft are limited in terms of size, weight, and power (SWAP), which in turn limits the data acquisition and signal processing capability of ground moving target indicator (GMTI) radars. SWAP limitations also affect the achievable signal to noise ratio due to the size of the antenna aperture. These restrictions make it difficult to detect and classify targets with small radar cross-sections such as dismounts. The complexity of GMTI radar systems on tier II UAVs may also be restricted to two channels. Having only two channels makes it challenging to mitigate ground clutter for detecting slowly moving targets during persistent, wide-area searches, i.e., when the antenna beams are broadside or squinted, while also providing accurate geo-location estimates of the targets.

Innovative GMTI signal processing approaches are needed to extend the capabilities of SWAP-limited systems and improve the state-of-the-art for target detection, localization, and classification. The goals of this SBIR are to develop and demonstrate advanced GMTI signal processing algorithms which address SWAP issues. Specifically, (i) detecting weak target signatures in clutter; (ii) robust feature extraction and target classification technique for dismounts, vehicles, livestock, low-flying aircraft, etc.); and (iii) simultaneous clutter suppression and target geo-location for systems having a small number of receive channels. Special emphasis will be given to difficult scenarios when performing surveillance over mountainous and/or urban environments where clutter is non-stationary, and SWAP limitations are even more problematic. Both broadside and squint modes will be considered.

PHASE I: Develop and demonstrate GMTI signal processing algorithms for SWAP-limited radar systems. Validate algorithms using modeling, simulation, and analysis tools. Conduct system trade studies, identify SWAP limited systems, and SWAP constraints on the radar processor. Create appropriate objective/threshold performance parameters for GMTI metrics which may include SINR, SINR loss, MDV, Pd, or Pfa.

PHASE II: Demonstrate and validate detection, geo-location, and characterization capability of the algorithm on airborne radar data. The data and its documentation (format, collection geometries, ground scenarios, etc) may be provided by the government or the contractor. The data must contain operationally relevant clutter environments to include urban areas and mountainous regions. The algorithms will be evaluated against developed metrics from Phase 1. Create a transition plan for this technology.

PHASE III: Military Application: Transition algorithms to medium altitude, long endurance UAV radar system(s) under development or currently in the DoD inventory. Commercial Application: GMTI capabilities have application for homeland security including counter-drug and border control.

REFERENCES:

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2. Soumekh, Mehrdad, “Synthetic Aperture Radar Signal Processing with Matlab Algorithms,” Wiley, 1999.

3. Ender, J. H. G., ``Space-time processing for multichannel synthetic aperture radar,'' Electronics and Communication Engineering Journal (February 1999), pp.29-38.

KEYWORDS: GMTI, radar, signal processing, data exploitation, Automatic Target Recognition (ATR), ground motion target indicator, automatic classification, clutter suppression

AF131-140 TITLE: Advanced Dual Band Apertures for improved early warning and space situational awareness missions

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Advance dual band aperture designs including T/R modules to increase early warning and space situational awareness radar system capability.

DESCRIPTION: Early Warning Radars are operated by 21st Space Wing squadrons for missile warning and space surveillance. This is a long- range, phased-array radar system. It is designed to detect and characterize a sea-launched and intercontinental ballistic missile attack against the United States. The system also has a secondary mission of Earth-orbiting satellite detection and tracking. Information received from the radar systems is forwarded to the United States Space Command's Missile Warning and Space Control Centers at Cheyenne Mountain Air Force Base, Colorado. The radar system is capable of detecting and monitoring a great number of targets that would be consistent with a massive submarine-launched ballistic missile (SLBM) attack. The system must rapidly discriminate between vehicle types, calculating their launch and impact points in addition to the scheduling, data processing and communications requirements.

The antenna of the existing radar system consists of multiple planar phased arrays operating at the UHF band. It has been recognized that a dual band system could significantly enhance the present system capabilities. The UHF band provides long range capability due to low propagation losses, and the higher band such as X-band offers high resolution and better tracking accuracy (range resolution better than 10 m and cross-range resolution better than 3 km for objects at a range of 2,000 kilometers).

This initiative will identify the performance benefits and potential challenges of a single band versus a dual band radar system (UHF/X), for EW and SAA missions. Performance objectives include wide area volume search, tracking, ballistic missile defense discrimination, and space object surveillance.

The contractor is encouraged to perform a first order system analysis including any associated constraints in spectrum access or interference in the proposed bands. The merits and challenges associated with an integrated dual band phased array aperture have to be included in the analysis. The ability to field the capability in the 2018+ time frame is a consideration, and therefore the technology readiness level of the technology will be an important factor. The current documented targets should be assumed, but the ability to address emerging threats must also be considered.

PHASE I: Perform a first order system study and recommend a second band for future EW/SSA radar systems. Design a dual band array considering latest technologies as well as retrofit (and/or add-ons) of the existing structures. Define the respective T/R module technology and RF/Digital beamformers. Predict the system performance improvements relative to the existing single band radars.

PHASE II:  Based on Phase I study, perform a detailed analysis and design of a small sub array.  Fabricate, measure and characterize the subarray.  Based on the measured data, assess the full system performance. Identify the technology readiness levels at subsystem and system level.  Provide recommendations on how to further mitigate risks, and develop rough cost estimate.

PHASE III:  Build a scalable sector of the array that would allow the measurements of the radar performance.  The array performance, in conjunction with the radar functions will be measured in a far field range.  The manufacturing and TRLs will be updated and cost inputs refined.

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2.  http://www.global security.org/space/systems/haystack.htm.

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4.  http://www.afspc.af.mil/library/factsheets/factsheet.asp?id=3656.

5.
https://www.fbo.gov/index?s=opportunity&mode=form&id=2f3973d6a7d33a330f489cad72702494&tab=core&_cview=0.


KEYWORDS: UHF, phased array, early warning radar, dualband, T/R module

AF131-141 TITLE: Antenna Design for Unmanned Aerial Vehicles

TECHNOLOGY AREAS: Electronics

OBJECTIVE:  Development of innovative antenna designs that provide UAV platforms with lightweight, low cost antenna solutions that increase their communications capacity and reliability.

DESCRIPTION:  The Department of Defense (DoD) is experiencing a dramatic increase in the development and use of drones across all of the armed services. This reflects what will be an even more aggressive effort in the future to expand the capabilities and role of drones. UAV usage across the military services jumped from nearly 165,000 flight hours in Fiscal Year (FY) 2006, to more than 258,000 in FY 2007. According to a 2009 Pentagon report [1], DoD plans to develop an "increasingly sophisticated force of unmanned systems" over the next 25 years. And while the use of UAVs by the DoD is growing, US law enforcement agencies and Homeland Security have recently also begun to investigate the use of UAVs as a critical resource multiplier [2].  The effort will confront some current shortfalls, including plans to improve how effectively drones rapidly and precisely locate and identify targets.  As UAV technology continues to advance, innovative antenna designs, optimized for these platforms, are needed to improve communications capability, reliability, and overall mission effectiveness.

UAV platforms present a number of challenges for good antenna design including significant installation impacts on antenna performance as no general purpose design philosophy exists. Typically, UAVs strive for flight endurance. Therefore minimization of payload weight and power consumption is critical. The platforms are often small, with an airframe generally fabricated using a lightweight composite material, with a significant portion of the available real estate for antennas being on, in, or near the wings. Installing antennas on or in the wing of the airframe presents challenges in that the wing has a low profile and a protruding antenna is generally undesirable.  Furthermore, during flight the wing can flex, degrading or altering the antenna’s performance characteristics.  Like manned airborne platforms, users strive to populate UAVs with significant electronics capabilities, therefore, minimizing the size and weight of these packages – especially the antennas – while maximizing mission capability is of high interest.

The focus of this effort is on communication links to and from (transmit and receive) Predator-class UAVs. These UAVs are relatively inexpensive, and therefore the inventory continues to grow, but antenna designs specifically for UAV platforms have not kept pace with these trends. The goal of this work is to look more closely at UAV design trends, identify the communication (command and control) needs for UAVs, and develop innovative antenna designs to enhance or expand the capability and reliability for these systems. As an example, the Wideband Gapfiller Satellite link would require RHCP at 30-31 GHz transmit, 20.2-21.2 GHz receive, capable of 100W CW with 80 dB isolation between transmit and receive with operational antenna pattern coverage from zenith to horizon represents a significant challenge on a Predator-class UAV. There are emerging material technologies that may enable antenna designers to develop antennas that are lighter weight and more flexible and that may also enhance user maintenance in the field.

PHASE I: Analyze trends in UAV design and commensurate communication system needs, and derive notional requirements for a medium data rate (~ 8 MBPS) BLOS (Ku or Ka band) comm links for Predator-class UAVs. Based on these requirements an antenna design will be developed, with emphasis on the verification of key proof of concept components. Size, weight, and cost of the concept(s) will be provided.

PHASE II: Demonstrate the antenna design. A prototype unit will be developed, and the performance characterized in an antenna measurement facility (which may be, but is not required to be, a Government facility) in a suitable test platform. Measurements will be compared with predictions. The installation method for the antenna system will be developed. Pointing and tracking methodology will be provided including mechanical design.

PHASE III: The antenna prototype unit will be demonstrated to TRL 6 in an environment relevant to an operational UAV platform.

REFERENCES:
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2. Hadal, Chad C. and Jeremiah Gertler, “Homeland Security: Unmanned Aerial Vehicles and Border Security,” Congressional Research Service, RS21698, 8 July 2010.

KEYWORDS: Antenna, UAV, communication

AF131-142 TITLE: Packaging High Power Photodetectors for 100 MHz to 100 GHz RF Photonic Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop optical pigtailing and packaging for newly developed high RF output power photodetectors (PDs); e.g. normal incidence, single ended, balanced and arrayed, modified uni-traveling-carrier, normal incidence PDs operating from DC up to 100 GHz.

DESCRIPTION: High frequency analog RF photonic links are desired to improve size, weight and power efficiencies for military RF antenna transmit and receive applications. State-of-the-art intrinsic RF performance and large dynamic range require fast, high-power photodiodes (PDs). In these systems PDs must be able to provide very high photocurrent level and thus, high output RF power to increase signal-to-noise-ratio while maintaining high linearity for large spurious-free dynamic range. However, there are two primary effects that impact high-power capability in PDs, which are space-charge screening [1], and thermal [2] effects. Recently, a charge-compensated modified uni-traveling-carrier (CC-MUTC) PDs with cliff layer [3] was demonstrated with record high output RF power up to 0.75 W at 15 GHz [4].

On-going developments have shown that improved and repeatable flip-chip processing leading to better thermal management and RF interconnects has increased the 3-dB bandwidth to 30 GHz. One way to overcome the trade-off between high speed and large saturation current, as an example, is to distribute symmetrically the optical signal to several PDs and combine their photocurrents by means of a transmission line. In this configuration, the optical signal is split by a power divider and fed into several discrete PDs, which are connected by an output transmission line. Due to the uniform optical power distribution, the photocurrent flowing through each PD scales inversely with the number of PDs. By embedding the discrete PDs within a transmission line, a traveling wave PD array can be formed [5].

PHASE I: Develop and provide packaging, with single-ended fiber optic pigtails and balanced pigtails, for government furnished normal incidence DC to 60 GHz MUTC PDs flip-chipped onto aluminum nitride (AlN) sub-mounts. The objective is to concurrently optimize frequency AND power handling capability. Investigate arrayed fiber optic pigtails designs.

PHASE II: Develop and provide packaging for government furnished photodetectors with single-ended and arrayed fiber optic pigtails for the DC to 100 GHz MUTC waveguide photodetectors flip-chipped onto synthetic diamond sub-mounts. Collaboration with existing AFRL partners is anticipated. The offeror may choose to provide their own photodetectors in addition to those furnished for packaging.

PHASE III: Ruggedize PD packaging and function over the full avionics operational environment. Ruggedized packaging is needed for military and commercial applications where extreme vibration and temperature exists. Conventional packaging would be useful for other applications, for example in an RF laboratory.

REFERENCES:
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3. Z. Li, H. Pan, H. Chen, A. Beling, J. C. Campbell, “High Saturation Current Modified Uni-Traveling-Carrier Photodiode with cliff layer,” IEEE J. Quantum Electronics, vol. 46, no. 5, 2010.

4. Beling, Li, Fu, Pan, and Campbell, “High-Power and High-Linearity Photodiodes,” 2011 IEEE Photonics Conference, pg. 19-20, October 2011.

5. Beling, Chen, Pan, and Campbell, “High-Power Monolithically Integrated Traveling Wave Photodiode Array,” IEEE Photonic Technology Letters, Vol. 21, No. 24, 2009.

KEYWORDS: Avionics, RF Photonics, Optoelectronic Packaging, High Power

AF131-143 TITLE: Computational Electromagnetics for a Systematic Security Evaluation and Countermeasure of Electromagnetic Analysis (EMA) on Electronic Security Devices

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop and demonstrate simulation tools, based on computational EM, to examine EM emissions from sensitive electronic devices, to identify physical leakages and design flaws, and to develop countermeasures and assess their effectiveness.

DESCRIPTION: Side-channel attack (SCA) vulnerability has posed a serious issue to the security of cryptographic devices [1]. The electromagnetic analysis (EMA) based side-channel attack is an efficient and powerful technique, by exploiting electromagnetic leakages emanated during a cryptographic operation, to retrieve secret information pertaining to the cryptographic implementations within an electronic package. It is well known that small and sensitive electromagnetic sensors can be used to extract data emanating from electronic devices. As we know, the electromagnetic radiations emitted from integrated circuits are mainly due to the displacement currents radiated through the layers, the wires, and the vias of circuit boards. Therefore, the attack sensors also intercept electromagnetic fields which are uncorrelated to the attacked crypto-processors. The current practice against the side channel attacks of electronic devices has been to evaluate the security of the hardware implementation after design and manufacture. In consequence, this iterative build-and-test process is usually very time consuming and costly.

With the advances of the modern computer technology and computational electromagnetics it is now possible to use fast full-wave electromagnetic methods to model high speed interconnects and passive components in electronic circuitries [2]. This project seeks to develop and demonstrate an electromagnetic analysis, attack, and countermeasure simulation software which will integrate a 3-D EM simulator to calculate electromagnetic radiation from electronic packages and an EMA data processing simulator to model various kinds of EMA attacks including SEMA and DEMA [3]. The EM radiation simulator can generate an electromagnetic radiation map to locate electromagnetic leakage spots and identify susceptibility in the design. The EMA simulator can be applied to simulate the electromagnetic attacks and their subsequent responses. The computational software developed can be used to examine electromagnetic emissions of electronic security devices and identify design flaws during the design stage. It also can be applied to develop countermeasures of EMA and assess their effectiveness.

PHASE I: Determine the appropriate computational electromagnetic models and develop prototype software to illustrate the effectiveness of electromagnetic attack analysis on an FPGA device.

PHASE II: Extend the software developed in Phase I to include more electronic components in an FPGA package. Demonstrate and validate the developed software by comparing with emission measurement data from the electronic device.

PHASE III: The developed software can be applied to counter the electromagnetic analysis attack techniques and secure the military sensitive integrated circuit devices, and can be applied in commercial applications including the consumer security devices and VLSI circuit design.

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KEYWORDS: Electromagnetic Analysis (EMA), Side-Channel Attack (SCA), Computational Electromagnetics

AF131-144 TITLE: <u>Low Power Multi-Channel RF and Digital GPS Anti-Jam ASIC</u>

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop and demonstrate a very small low power integrated multi-channel RF and digital anti-jam (AJ) ASIC for integration within SWaP constrained military GPS receivers and capable of being interfaced to a small multi-element antenna array.

DESCRIPTION: Military global positioning systems (GPS) receivers require protection against all forms of interference, intentional and unintentional. Controlled Reception Pattern Antennas (CRPAs) and associated Antenna Electronics (AE) have been used successfully on numerous platforms to form nulls in the direction of interference signals while maintaining enough gain toward satellite signals to support GPS navigation. Nulling and beam steering electronics are in use today to interface CRPA/AEs to military GPS receivers and provide improved signal reception in an interference environment. Although these electronics provide excellent performance, they do so at a significantly increased size, weight, power and cost (SWaP-C) to the GPS integration on the platform. Advances in RF and digital packaging technologies as well as the continued advance of Field Programmable Gate Arrays (FPGAs) to support rapid prototyping and development are enabling various components to be combined onto a single Application Specific Integrated Circuit (ASIC). The goal of this program is to integrate multi-channel RF front-end and Digital AJ processing circuitry onto a single ASIC and interface this device with next generation military GPS receivers. The ASIC must accept signals directly from CRPA, amplify, down convert and filter the RF antenna signals, perform A/D conversion, and apply digital signal processing algorithms to simultaneously reduce or eliminate interference signals in the 24 MHz bandwidths centered at the L1 (1575.42 MHz) and L2 (1227.60 MHz) while still passing GPS signals in the L1 and L2 24 MHz bandwidths to support acquisition, tracking and navigation. Basic objectives for the ASIC include: size suitable for integration within a SWaP-constrained GPS receiver (e.g., handheld), accept RF inputs from a minimum 2-element (Objective: 4-element) CRPA simultaneously at L1 and L2 GPS frequencies, provide at least 30dB of anti-jam protection for up to 2 (Objective: 3) 24MHz wide gaussian noise interference sources (assume well matched CRPA RF antenna outputs), successfully pass GPS M-code signals that can be used by modernized GPS receiver for navigation, and consume a total power of 1 Watt or less.

Approach encourages technology development practices that eventually result in improved performance and lower cost and size for commercial products. The Government will provide a full set of antenna array data to support the development.

PHASE I: Review of AJ GPS requirements, assess CRPA data, identify GPS receiver interface requirements. Trade study of potential RF design and AJ processing algorithms as well as a recommended solution. Preliminary multi-channel RF-Digital architecture including RF downconversion, filtering, A/D conversion and AJ signal processing. Preliminary simulation and verification of design in prep of final design.

PHASE II: Objective is to fabricate an ASIC and test fixture capable of demonstrating performance. Finalize ASIC design and layout, and demonstrate performance through simulation and/or prototyping. Develop a test plan to verify standalone performance and when interfaced to a GPS receiver. Test and evaluate the ASIC to show basic functionality. Deliver the ASIC and test fixture for additional government test and evaluation. Document design and test results in a final report.

PHASE III: Technology developed will expand current application of GPS AJ technology. Use of state of the art technologies that shrink the SWaP-C may help control cost of future civilian and military GPS receivers operating in interference environments.

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4. Author unknown, “How the Army Uses Embedded GPS for Combat Service Support in the Movement Tracking System (MTS)”, Pathfinder Newsletter, Volume 14, Issue 3, July, 2007.

KEYWORDS: GPS, anti-jam, CRPA, digital signal processing, mixed signal ASIC

AF131-145 TITLE: Light Weight High Gain High Data Rate Launch Vehicle Antenna

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Investigate alternative SATCOM links and develop novel high bandwidth, high gain antenna designs to achieve higher data rates for the link between the EELV booster and the GIG as it traverses from the launch pad to the end of powered flight.

DESCRIPTION: Evolved Expendable Launch Vehicles (EELV's) have a requirement to monitor the upper stages during orbit insertion and disposal in order to detect and recover from anomalies observed in flight. Video monitoring of the flight is desirable and requires data rates of 10-20 Mbps. Existing EELV antennas can support the required data rates while within line-of-sight (LOS) of the ground terminal, but when the vehicle leaves LOS it converts to a satellite communications (SATCOM) data link with a lower data rate that does not support the desired video monitoring of the flight. The existing EELV antennas use a Tracking and Data Relay Satellite (TDRS) S-band link, which limits data rates to < 400 kpbs, but there may be alternative SATCOM links at other frequencies that are available for future use and that can support higher data rates. Some potential SATCOM data links have been identified in previous studies, but a thorough evaluation of the alternative SATCOM links is needed to assess their availability and performance. Examples of alternative SATCOM links include Iridium and Inmarsat at L-band frequencies and the TDRS Ku- and Ka-band links. In addition to identifying alternative SATCOM links, new high-gain, high bandwidth antenna designs and architectures are needed. These antennas must support 10-20 Mbps data rates over the selected SATCOM link, with near-hemispherical coverage from launch to end of powered flight. A comprehensive trade-off study of the possible data links and their impact on antenna design/performance (gain requirement, coverage requirement, polarization requirement, etc.) should be a key technical task for Phase I.

New designs must also meet the physical limitations surrounding launch vehicle external telemetry antennas. Antenna height above the launch vehicle surface (a function of aeroheating) and depth behind the skin of the vehicle (due to impacts on internal structures), as well as surface area (antenna aperture) are a few of the more important physical concerns when considering a launch vehicle antenna and will often determine where an antenna may be mounted. There are, of course, other environmental requirements (shock, vibration, etc.) as well as electrical requirements (power handling, coupling, etc.) that further define the antenna attributes. The antenna must meet the size, weight and power (SWaP) constraints of EELV's, using the existing power supplies and without significant changes to the footprint of the antenna on the launch vehicle. The specific physical, environmental and electrical requirements should be explored and identified in the Phase I effort and be used to constrain the antenna design.

PHASE I: Investigate alternative SATCOM links that can be used to support high data rates. Perform a trade-off study to select the best data link. Develop a preliminary antenna design utilizing the selected data link and meeting the identified physical, environmental and electrical constraints. Demonstrate through simulation and analysis that the antenna concept can support the required data rates.

PHASE II: Fabricate a prototype antenna based on the results at the conclusion of Phase I. Characterize the antenna through comprehensive S-parameter and gain measurements. Use measured data to predict the system level performance, including a full link analysis. Use a combination of testing and analysis to evaluate antenna performance under realistic launch vehicle environmental conditions.

PHASE III: Military Application: EELV telemetry antennas and other future follow-ons to EELV. Commercial Application: With commercialization of the space program, newly developed commercial launch vehicles will require similar technology for telemetry antennas.

REFERENCES:
1. Welch B and Greenfeld I, "Launch Vehicle Communications," NASA/TM-2005-213418, published by National Aeronautics and Space Administration, Glenn Research Center, Cleveland, OH, Jan 2005.

2. Whiteman D, Valencia L, and Birr R, "Space-Based Telemetry and Range Safety Project Ku- and Ka-Band Phased Array Antenna," NASA/TM-2005-212872, published by National Aeronautics and Space Administration, Dryden Flight Research Center, Edwards, CA, July 2005.

3. Range Commanders Council Telemetry Group, "Telemetry (TM) Systems Radio Frequency (RF) Handbook," RCC Document 120-08, published by the Secretariat, Range Commanders Council, US Army White Sands Missile Range, New Mexico, March 2008.

KEYWORDS: Keywords: launch vehicles, telemetry antennas, conformal antennas, phased array antennas, satellite communications, space-based range

AF131-146 TITLE: <u>Space based Hyper-Spectral Imaging Sensor</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a space hosted Hyper-Spectral Imaging [1][2] sensor for Battlespace Awareness (BA), capable of targeting dynamic events and/or energetic battlefield objects (missiles, bomb blasts, aircraft, artillery fire).

DESCRIPTION: This solicitation seeks development of an innovative hostable or free flyer space based hyperspectral imaging (HSI) sensor to increase target detection for the Battlespace Awareness and possibly Strategic Missile Warning mission areas. In particular, the SBIR will address development and application of HSI technologies to improve space-based target detection during suboptimal conditions such as viewing objects against sun-lit clouds. To perform the missions, the sensor will be required to image a large region of the earth by staring, scanning, or step-stare, with appropriate revisit rates.

The effort will begin in Phase I with a Design Trade Study to address the mission requirements and how alternate HSI sensor system designs address the requirements. These trades should include field of view and sampling rate versus target velocity within the scene, focal plane array size, number of spectral bands, spatial resolution, scanning method (e.g. Fourier Transform/scanning Fabry-Perot, Cross Dispersive Prisms, dispersive linescan, etc.) and time to capture a spectra. The following key parameters may be used as initial goals to guide the design study: spectral range (1 - 5 microns), image size (512 x 512 or larger), spectral resolution (10 - 50 nm), and spectrum capture time (10 - 100 ms). The trade study should include predicted system performance. The design trade recommendations should be developed into a system design capable of performing the Battlespace Awareness and Strategic Missile Warning missions at representative altitudes. The technologies for the system design will be demonstrated first as a prototype HSI system for a ground or airborne proof of concept, and ultimately as a space qualified HSI sensor for space flight test.

The Design Trade Study / System Design must address operating the HSI system in space. Space survivability in the orbital environment based on radiation hardening or design practices should be addressed. The technology shall be capable of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and five years in Low Earth Orbit (LEO) after up to five years of ground storage.

This project is ITAR restricted. No foreign persons as defined in appropriate laws and regulations governing ITAR may work on it.

PHASE I: Address the design trades for a space-based HSI surveillance system. Trades should include field of view & sampling rate vs. target velocity within the scene, focal plane array size, number of spectral bands, spatial resolution, scanning method and time to capture a spectra. Design trades should be developed into a prototype design capable of performing the missions at representative altitudes.

PHASE II: Fabricate and deliver the prototype sensor hardware for a ground or air based proof of concept. The work will address space qualified flight issues. The sensor hardware should address only the sensor system, but be capable of integration into the larger system foreoptics. The final report should include performance analysis (coverage and detection analysis) and should develop the process, procedures, and cost required to fabricate, test and deliver a turn-key space qualified HSI sensor.

PHASE III: Build a space qualified HSI sensor & integrate into a space system for flight test. Military uses for this space-based HSI concept are battlefield surveillance and threat warning. Non-military uses for space-based HSI include combustion analysis.

REFERENCES:
1. (Reference removed from topic on 12/14/12.)

2. Development of a AIRIS-WAS Multispectral Sensor for Airborne Standoff Chemical Agent and Toxic Industrial Chemical Detection, PSI-PR-1214, http://www.psicorp.com/library/publication_cat.html?pid=523, William Marinelli, Christopher Gittins, Bogdan Cosofret, Teoman Ustun, and James Jensen.

3. M. Chamberland, V. Farley, A. Vallières, L. Belhumeur, A. Villemaire, J. Giroux et J. Legault, "High-Performance Field-Portable Imaging Radiometric Spectrometer Technology For Hyperspectral imaging Applications," Proc. SPIE 5994, 59940N, September 2005.

KEYWORDS: Space, hyper-spectral imaging, targets, sensors, Multi-bands

AF131-147 TITLE: Affordable Sub-array for TT&C Phased Array Antennas

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design, develop, and demonstrate the feasibility of a low-cost subarray architecture for large communication phased array antennas used to support space satellite operations.

DESCRIPTION: Phased array antennas have demonstrated the high performance in throughput, responsiveness, flexible operability and lower maintenance cost required for Air Force communication and surveillance mission operational support. However the acquisition cost of active phased array antennas is the single most significant factor hindering their wide application in both military and commercial fields. For example, cost is a major impediment to the realization of a large hemispherical phased array antenna useful for horizon-to-horizon simultaneous coverage of multi-satellite TT&C systems such as that employed by the Air Force Satellite Control Network. The cost of the transmit/receive (T/R) modules, subarray, and associated control electronics may constitute over half of the total antenna cost [1, 2] While efforts are currently underway to reduce the cost of the T/R module to less than $100 per unit, efforts to reduce the cost of the subarray (radiating elements, RF beam former, DC and control distribution, T/R module retention, structure, etc.) still need to be undertaken to reduce costs that are currently on the order of $140 per radiating element. The objective of this solicitation is to design, develop, and demonstrate the feasibility of very low-cost (below $100 per element in high volume production) subarray concepts for large communication phased array antennas through innovation of cost-effective element design, interconnect and architecture, and material technologies.

The antenna subarray developed under this effort should provide equivalent performance to the current state-of-the-art L- and S-band subarray developed under the Geodesic Dome Phased Array Antenna (GDPAA) program [1,5]. This design consists of a multi-layer printed circuit board radiating element aperture and network, as well as the control, interface and support structures. Likewise, the new subarray must include these components and be able to support simultaneous transmit and receive with high isolation (>45 dB), full-duplex multiple beams (at least one transmit and two receive beams from a single subarray), 120 degree field-of-view, and high gain over noise temperature from a single operating phased array antenna. The subarray shall be capable of interfacing T/R modules with array elements. The latest T/R module form factor will be provided by the government at the start of Phase I, but alternatives to this interface should be part of the Phase I study. Real-time replacement of T/R modules to support hot maintenance requirements is desired, but alternatives to this approach could be considered if they provide significant cost savings.

The Phase I effort shall identify innovative low cost radiating element and RF/DC architectures and assess technical issues associated with specific architectures and fabrication approaches. Candidate design concepts shall be assessed in terms of their performance (amplitude and phase errors, frequency bandwidth, isolation, loss, power handling, etc.), feasibility, manufacturability, reliability and cost. The effort shall document and rank subarray candidates for Phase II development.

In Phase II a candidate subarray design will be selected based on numerical simulations and trade-off studies of performance, manufacturability, reliability, cost, adaptability, etc. A complete prototype subarray assembly will be fabricated and tested and the subarray measured values will be compared with simulated results. The Phase II effort shall also identify efficient manufacturing, test and quality control processes for large quantity production, perform realistic production cost and timeline analysis, and assess the feasibility and cost of integrating the antenna subarray into a large phased array antenna for space mission support.

PHASE I: Phase I activity shall include: (1) develop subarray performance requirements for supporting satellite operations; (2) develop subarray architecture concepts to support those requirements; (3) identify technical issues for selected architectures/fabrication approaches; (4) assess candidate designs in terms of performance, cost, etc; and (5) document subarray candidates for Phase II development.

PHASE II: Based on the Phase I results, the contractor shall: (1) select the most promising subarray design by performing numerical simulations and refining trade-offs on performance, manufacturability, reliability, cost, adaptability, etc.; (2) fabricate a prototype subarray antenna assembly of a size and format to be negotiated between the Contractor and the Government; (3) test the subarray and compare with simulations; (4) perform realistic cost analysis including production and integration costs.

PHASE III: The antenna subarray can be used to reduce the cost of large phased array antennas for satellite communication and space control. The antenna subarray is equally applicable to commercial satellite control operations.

REFERENCES:
1. Henderson, M., "GDPAA Advanced Technology Demonstration Overview and Results," 2010 IEEE International Symposium on Phased Array Systems & Technology, 12-15 Oct. 2010, Boston, MA.

2. Liu, S. F., Survey of Phased Array Antenna for AFSCN Application, May 1998.

3. Tomasic, B., Analysis and Design Trade-Offs of Candidate Phased Array Architectures for AFSCN Application, Presentation to the Second AFSCN Phased Array Antenna Workshop, Hanscom AFB, April 1998.

4. Mailloux, R. J., Phased Array Antenna Handbook, Artech House, 1994.

5. Sarjit Bharj, Boris Tomasic, Gary Scalzi, John Turtle and Shiang Liu, "A Full-Duplex, Multi-Channel Transmit/Receive Module for an S-Band Satellite Communications Phased Array", IEEE 2010 International Symposium on Phased Array Systems and Technology, 14-18 October 2010.

KEYWORDS: Large Phased Array Antenna, Simultaneous Transmit and Receive, Antenna Subarray, Radiating Element, RF Beam Forming Network, Feed Network, Satellite Control

AF131-148 TITLE: Low cost Diplexer for High performance phased array antenna

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop low cost, low insertion loss, high isolation, and small form factor diplexer technology to enable full duplex transmit/receive systems for SGLS/USB-Bands operation.

DESCRIPTION: A low-cost phased-array antenna is capable of improving commercial and military satellite control network performance and reducing acquisition, maintenance, and operational cost. Transmit/Receive (T/R) modules for S-Band multi-beam Geodesic Dome Phased-Array Antenna (GDPAA) have been manufactured for nearly a decade for satellite communication systems. Currently, the T/R module implementation approach is based on the hybrid assembly technique that includes two ceramic resonator-based diplexers for proper isolation between the transmitter and receiver. These diplexers are utilized in the module to allow full-duplex with multiple simultaneous communication links which presents a significant technical challenge as the size of the T/R module is reduced. These diplexers employ surface mount technology where the receiver function operates at S-Band across 2.2-2.3 GHz and the transmit function has two channels that operate at the Unified S-Band (USB) and the Space Ground Link System (SGLS) Band, respectively. Other critical parameters for the diplexers are: (1) rejection between transmit and receive bands should exceed 65 dB; (2) power handling of 2-Watts minimum, (3) low insertion loss of less than 1 dB, and (4) small form factor for interfacing with a single IC T/R chipset. The diplexer will operate in a ground based environment. A description of the state of the art for performance and form factor is given in Ref. 2 "Unbalanced to balanced and balanced to unbalanced diplexer".

Presently the T/R function is being developed as a Monolithic Microwave Integrated Circuit (MMIC), which will reduce the overall module size, component count, and ultimately lead to cost reduction. Thus improving the diplexer technology will be a key factor to enable overall size and cost reduction of the T/R module. This solicitation seeks innovative techniques to enable very small size and low insertion loss diplexers that can be manufactured in an appropriate technology and mass produced with cost being a key driver. The contractors are encouraged to explore emerging technologies and innovative topologies that will dramatically reduce component size and cost while simultaneously improving performance. Technologies that utilize soft substrates with metal backing, low temperature co-fired ceramic, or multilayer ceramics may be explored.

A preliminary design identifying the technology with a detailed plan to implement the diplexer is required. In addition, a detailed cost analysis for large quantity production is also required deliverables.
No government materials, equipment, data or facilities are required to be used on this effort.

PHASE I: Develop the concept for low insertion loss, low cost, and high isolation diplexer for L/S-Band operation. Fabrication technologies will be evaluated to realize the high performance diplexer to enable CSWAP optimization of the transmit/receive module.

PHASE II: Demonstrate the novel L/S-Band diplexer technology by design, fabrication, and characterization of the diplexer component.

PHASE III: Military Application: Integrate the diplexer into a T/R module for system demonstration.
Commercial Application: Commercial applications may be in the area of satellite communication systems.

REFERENCES:
1. Sarjit Bharj, Boris Tomasic, Gary Scalzi, John Turtle and Shiang Liu, “A Full-Duplex, Multi-Channel Transmit/Receive Module for an S-Band Satellite Communications Phased Array”, IEEE 2010 International Symposium on Phased Array Systems and Technology, 14-18 October 2010.

2. Xue, Q., Shi, J. and Chen, J. X., “Unbalanced to balanced and balanced to unbalanced Diplexer”, IEEE MTTT, Nov 2011.

3. Liu, S.F., "A Preliminary AFSCN System Concept Using Phased Array Antenna," May 1998.

4. Tomasic, B., Analysis and Design Trade-Offs of Candidate Phased Array Architectures for AFSCN Application, Presentation to the Second AFSCN Phased Array Antenna Workshop, Hanscom AFB, April 1998.

KEYWORDS: diplexer, transmit/receive module, hybrid integration, isolation, insertion loss

AF131-149 TITLE: GNSS Antenna Arrays for Situational Awareness

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop multi-platform Global Navigation Satellite System (GNSS) antenna array capabilities for situational awareness (SA), providing direction finding and geo-location of the GNSS signals.

DESCRIPTION: Single element and co-located multi-element antennas are being developed to receive navigation signals in the GNSS frequency band, covering the GPS, GLONASS, GALILEO, and COMPASS navigation systems. This next generation GNSS user equipment must be capable of operating in an electronically challenging environment and providing situational awareness of this environment to enhance mission planning and weapon system effectiveness. Multi-element antenna arrays are of particular interest for next generation GNSS systems, since they can provide both the anti-jam (A/J) and situational awareness (SA) capabilities that are required for operation in these environments. Direction finding and geo-location of GNSS signals for SA is the primary focus of this SBIR topic. Although A/J GPS capability is desirable (Reference 1), it is not a requirement for this effort.

Direction finding (DF) algorithms that are used with arrays of antenna elements are well-established, Reference 2, and their use in geo-location of GPS signals has been demonstrated, Reference 3. More recently, a ground-based operational prototype system targeted to GNSS interference source detection and localization was demonstrated, Reference 4. This system was implemented with a spatially distributed array of sensor nodes and was capable of simultaneous localization of multiple emitters. This SBIR topic seeks to expand on these previous efforts by developing multi-element antenna arrays for both manned and unmanned air vehicles that cover the full GNSS band and that can provide SA capabilities, while meeting the size, weight, power and cost constraints of these vehicles. There are three critical aspects in designing capabilities for this type of antenna array: a) antenna elements that cover the full GNSS frequency band (1160 - 1600 MHz) with sufficient gain, bandwidth and radiation pattern stability to perform the SA function, while at the same time minimizing cost, size, and weight; b) simple connectivity of the data from the antenna elements to a central processor; and c) robust SA algorithms. This SBIR should concentrate on novel technologies for the multi-band elements, array configuration and connectivity (a and b), while utilizing generic processing algorithms for the SA processing (c), with the goal to indicate the robustness of the design over the GNSS frequency band. Alternative element designs and array configurations should be studied under this effort to accommodate integration into a range of different sized air vehicles, from smaller unmanned air vehicles to larger aircraft, such as the F-16. A larger antenna array could obtain more accurate SA capability, but would increase the cost and complexity of integration into the platform. Distributing the antenna array elements across the platform could be considered, as it would result in a larger antenna, with more accurate SA capability than a single co-located multi-element antenna, but this configuration could also result in sharp variations in the pattern, which must be considered in the processing. Trade-offs in element/array size and placement, as well as cost, weight, power and processing requirements should be considered in the Phase I study. Alternatives for communications and connectivity between the elements and the central processor should also be considered in the design trade-off study.

PHASE I: Develop antenna elements that cover the GNSS band and approaches for combining the elements into a networked array (using modeling, simulation, and sub-scale prototypes if possible). Show that these approaches will work over the GNSS frequency band, are technically feasible, and are reasonable with respect to size and weight for different platforms from UAV's to larger aircraft.

PHASE II: Utilizing the design from Phase I, fabricate and demonstrate a prototype system that combines a number of GNSS elements into a networked array on a platform (representative ground-plane), which wirelessly communicates data to a central processor. Test the resulting system to demonstrate the combined antenna performance over the GNSS frequency band and the capability of obtaining SA information.

PHASE III: Follow-on activities are expected to pursue in both military and commercial applications for schemes which network different antennas (not all with full GNSS capabilities), on and off platform, for the GNSS SA applications.

REFERENCES:

1. Air Force SBIR Phase I Topic AF 083-159, Combining Remotely Located GPS Antennas on UAV Platforms, 2009.

2. Van Trees, H.L. “Optimum Array Processing, Part IV” Wiley, 2002.

3. Isoz,O. A., Balaei, T. and Akos, D. "Interference detection and localization in the GPS L1 band," in Proceedings of the ION ITM, (San Diego, CA), pp. 925-929, Institute of Navigation, Jan. 2010.

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5. Mailloux, R. J., Phased Array Antenna Handbook, Artech House, 1994.

KEYWORDS: Antenna Array, GNSS, Distributed Array, Direction Finding, Situational Awareness, Geo-location

AF131-150 TITLE: Coherent Imaging Laser Source

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop an innovative, flight compatible, high-energy, pulsed laser system for use with coherent imaging systems.

DESCRIPTION: Coherent imaging systems have the capability to provide high-resolution 3D imagery for target identification at stand-off ranges. Coherent imaging methods which combine image synthesis and multi-wavelength 3D imaging offer exciting possibilities for future imaging systems [1-3]. These systems theoretically provide arbitrarily high target depth precision without the need for high-bandwidth detectors and modulators. The holographic imaging techniques may also lead to low volume, conformal active imaging systems. Unfortunately, these systems require relatively short, transform-limited linewidth pulsed lasers with high per-pulse energy to illuminate the target of interest.

Current state of the art narrow linewidth (<100kHz) pulsed fiber laser systems around 1550 nanometer wavelength region are limited to ~100 microjoules for the pulse durations desired. While state of the art Q-switched lasers do have sufficient pulse energies they do not have sufficiently narrow linewidths and/or access to a continuous wave (CW) seed laser with the same wavelength as the pulsed output. An innovative and novel solution is required in order to design a laser system capable of delivering high energy pulses for standoff coherent imaging applications.

Systems designed to utilize coherent imaging techniques would require high-energy, transform-limited pulses to ensure adequate Signal-to-Noise Ratio and to maintain coherence throughout the target volume. High pulse energies allow larger areas to be imaged; pulse energies of greater than 10 millijoules may be required to image extended targets of interest at range. Pulse lengths between 30-300 nanoseconds should strike a balance between freezing target motion and providing coherent return across a relatively deep target. The laser wavelength chosen should have high atmospheric transmission and be between 1.4 and 1.7 microns to mitigate eye-safety risks and allow the surrounding imaging system to utilize commercial-off-the-shelf fiber components and detector arrays. Longer wavelengths may be considered as long as suitable detector arrays and additional electro-optic components are identified that enable the short pulse, shot noise limited, digital holography techniques desired. While a Master Oscillator Power Amplifier architecture is not necessarily required, access to a CW "seed" output is required to provide a local oscillator for the imaging sensor. The system must have an adequate gain bandwidth over 10's of gigahertz to support multi-wavelength imaging techniques.

In summary, the proposed system should have limited pulses with lengths between 30-300 nanoseconds, pulse energies greater 10 millijoules, while providing a CW seed source for coherent mixing with the return beam. Pulse repetition rates should be scalable to 1 kHz or greater. The proposed system should operate at an eye-safe wavelength with high atmospheric transmission. The ultimate goal is to develop a laser system that is flight compatible with minimal size, weight and power (SWAP) [i.e. high wall-plug efficiency]. These considerations should drive any design solution.

PHASE I: The effectiveness of various candidate concepts will be evaluated. Preliminary designs will be modeled and fabrication feasibility of those designs will be evaluated. Shortcomings in fabrication and critical technology that would require additional development during Phase II will also be identified.

PHASE II: A prototype laser which demonstrates key design principles will be developed and tested. A path towards a producible, low-SWaP laser system will be described.

PHASE III: A flight compatible laser system will be developed as part of a holographic ladar sensor and integrated into an electro-optic sensing pod for performing identification at tactical standoff ranges.

REFERENCES:
1. J. Marron and K. Schroeder, "Holographic laser radar," Opt. Lett. 18, 385-387 (1993).

2. T. Höft, R. Kendrick, J. Marron, and N. Seldomridge, "Two-Wavelength Digital Holography," in Adaptive Optics: Analysis and Methods/Computational Optical Sensing and Imaging/Information Photonics/Signal Recovery and Synthesis Topical Meetings on CD-ROM, OSA Technical Digest (CD) (Optical Society of America, 2007), paper DTuD1.

3. David J. Rabb, Douglas F. Jameson, Jason W. Stafford, and Andrew J. Stokes, "Multi-transmitter aperture synthesis," Optics Express Vol. 18, pp. 24937-24945 (2010).

KEYWORDS: laser, pulsed laser, digital holography, ladar, laser radar, optics

AF131-151 TITLE: Speedy Sparse Bundle Adjustment for Video/Image Sequences

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop robust, rapid, and automated Sparse Bundle Adjustment software to create and update the camera extrinsic and intrinsic parameters for a set of input images or video frames faster than the current state of the art.

DESCRIPTION: Sparse bundle adjustment (SBA) has been a solved problem since the 1960's. Modern computers have made the SBA process computationally tractable and it is particularly useful for 3-D reconstruction to determine the extrinsic and intrinsic parameters of a moving camera (1). Automatic determination of extrinsic and intrinsic parameters of a camera will result in more autonomy of surveillance systems and deliver better data to the war fighter. The state of the art implementations are Bundler (4) and Visual Structure from Motion (2) which utilizes multi-core bundle adjustment (MCBA). These implementations work well but they are slow because they do not assume any spatial or temporal order to the input images. For Air Force applications the images are likely to be in a logical spatial-temporal order therefore we hope we can gain a tremendous speed improvement by processing images in order. A robust fully automatic speedy sparse bundle adjustment algorithm will help the USAF operate surveillance systems in GPS denied airspace plus automate the process of building a camera model. Modeling a camera is a time consuming process that often requires a specialized skill set hence an automatic camera model process is desired. We are looking for an open technology development (5) that builds on the existing sparse bundle adjustment (SBA) foundational work which makes dramatic performance improvements. The offeror should consider implementations that will utilize graphics processing unit (GPU) acceleration (either OpenCL or CUDA) so the software will run on commodity CPU(s) or GPU(s). A flexible/robust system is the desired end result, thus successful offerors will allow the software to use a multitude of existing feature detection algorithms such as scale-invariant feature transform (SIFT), speeded up robust features (SURF), and oriented fast rotated brief (ORB), etc. Output is a simple camera matrix with typical values for the camera position, orientation (extrinsics) and focal length, principal point, and distortion factor (intrinsics). The proposal should specify datasets used for both full motion video (FMV) and wide area motion imagery (WAMI) sensors. The government will provide potential baseline datasets on the public release site of the AFRL Sensor Data Management System (3).

PHASE I: The expected product of Phase I is a speedy sparse bundle adjustment algorithm that takes as input a single stream of EO visible airborne imagery and builds the camera matrix for each frame (both intrinsic and extrinsic) documented in a final report and implemented in a proof-of-concept software deliverable.

PHASE II: The expected product of Phase II is a prototype implementation of the Phase I proof of concept algorithm, enhanced to include faster run times by operating on both multiple CPUs and multiple GPUs. Report/illustrate demonstrated improvements.

PHASE III: DUAL USE COMMERCIALIZATION: Military Application: Visualization, training, combat search and rescue. Commercial Application: Mapping and navigation, city planning, emergency response.

REFERENCES:
1. Jeong, Y., Nister, D., Steedly, D., Szeliski, R., and Kweon, I., "Pushing the Envelope of Modern Methods for Bundle Adjustment", 2012, IEEE Transactions on Pattern Analysis and Machine Intelligence.

2. Wu, ChangChang, "VSFM: Visual Structure from Motion", 2012, http://www.cs.washington.edu/homes/ccwu/vsfm/.

3. AFRL/RYA "SDMS: Sensor Data Management System", 2012, https://www.sdms.afrl.af.mil/.

4. Snavely, N, "Bundler: Structure from Motion (SfM) for Unordered Image Collections", 2012 http://phototour.cs.washington.edu/bundler/.

5. DoD CIO's Office, "Open Technology Development (OTD): Lessons Learned & Best Practices for Military Software", 2011, http://dodcio.defense.gov/Portals/0/Documents/FOSS/OTD-lessons-learned-military-signed.pdf.

KEYWORDS: EO, visible, airborne imagery, algorithms, denied airspace, autonomy, GPGPU

AF131-152 TITLE: Low Noise Photonic Oscillator in Short-Wave Infrared (SWIR) Band

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Perform feasibility study to develop very narrow, stable photonics oscillator capable of operation in Short-Wave Infrared (SWIR) band.

DESCRIPTION: High-performance SWIR transceiver plays the critical role in sensing, ranging, jamming and fire control systems for airborne systems. Laser radar (LADAR) systems operating in SWIR band carry particular importance as they provide the access to low-loss sensing and communication window. Indeed, SWIR band is populated by important spectral fingerprints of jet/rocket propulsion systems; LADAR target acquisition and fire control possesses qualitatively larger range than that in conventional near infrared (NIR) band.

In order to realize the advantage inherent to SWIR-band LIDAR band, it is necessary to provide local oscillators with performance that is at least comparable or better than the existing NIR devices. Specifically, this means that SWIR photonics oscillator should possess a) linewidth below 30Hz; b) relative intensity noise (RIN) below -160dB/Hz in immediate carrier vicinity and c) sufficient optical power. If realized, SWIR-band oscillator would qualitatively improve the performance of high-sensitivity systems such as synthetic aperture radars (SAR), LIDARs and airborne data links [1].

The performance of the state-of-the-art oscillators fundamentally depends on the cavity construction and its underlying stability [2]. Indeed, spectrally narrow emission from a stable laser requires that a highly resonant cavity be brought to thermal and mechanical equilibrium. While passively or actively stabilized cavities can, at least in principle, be fabricated equally well in both NIR and SWIR bands, materials providing optical gain in NIR band are vastly superior. Worse, the SWIR gain mechanisms rely on less efficient, noisy and narrow-band processes [3].

Consequently, new approach to construction of highly stable, low-noise photonics oscillators operating in SWIR band is required. A new path towards the construction of SWIR oscillator should address the following set of minimum requirements:
1) Spectral band coverage up to minimum of 2200nm; preferred coverage includes contiguous NIR/SWIR bands;
2) Spectral linewidth commensurate with long rage coherent sensing and communication requirements; maximal linewidth below 30Hz;
3) Minimum optical power of 100mW. Any solution that combines the above technical targets with frequency agility (tunability) is particularly encouraged.

If the practical SWIR oscillator can match the state-of-the-art NIR performance, the resulting device would provide fundamentals for re-engineering of high-performance SAR/LIDAR systems, doubling their range and inherent sensitivity.

PHASE I: Perform feasibility study for practical design of narrow SWIR oscillator possessing a) spectral linewidth below 30Hz, b) operating in minimum spectral range defined by 1900nm (or lower) and 2200nm (or higher) and c) minimum 100mW of optical power in continuous (CW) or quasi-CW operational regime. Phase I is expected to derive the formal plan for Phase II effort.

PHASE II: Using the design from Phase I, practical device design should be derived and subcomponents tested. Phase II work design is expected to result in prototype unit construction. The prototype must support at least two of three critical parameters: linewidth, full SWIR coverage and higher than 100mW power.

PHASE III: A demonstrator SWIR oscillator compatible with pollution (carbon) and HF sensing requirement should be assembled and tested. Two separate applications (commercial/military) should be targeted by specifically designing the fieldable units.

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3. T.B.Simpson, Jia-Ming Liu, Nicholas Usechak and Vassilios Kovanis, “Tunable Photonic Microwave Oscillator Self-Locked by Polarization-Rotated Optical Feedback,” Timing and Frequency Symposium Proceedings, IEEE 2012.

KEYWORDS: LIDAR, LADAR, Coherent communications, SWIR sensing, Free-Space Communication, Spectral Sensing, Pathogen and Chemical Detection

AF131-153 TITLE: Precise Estimation of Geo-location Uncertainty

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To automatically compute precise geo-location uncertainty estimates for aerial imaging systems. Uncertainty estimates for systems that utilize computer vision-based algorithms to generate geo-location estimates are of particular interest.

DESCRIPTION: With the continuing increase in the quantity and capabilities of systems that capture aerial imagery, a large amount of video and motion imagery is being collected to provide warfighters with increased situational awareness. However, while imagery by itself is helpful, knowing the context of the imagery is often as important as the imagery itself. For example, a simple video of a person walking on a road does not give the warfighter much information. On the other hand, seeing a video of a person walking down a road, while knowing what road the person is walking on, in which direction they are walking, what other people and objects are nearby, and information about what other traffic typically exists near that location gives the warfighter a tremendous amount of information. Therefore, it is important that the geo-location of all imagery collected be accurately estimated.

If perfect estimates of geo-location were achievable, then simply returning the geo-location of the imagery would be sufficient. However, because no geo-registration solution will be perfect, it is essential that the geo-location estimation system also return the uncertainty in its estimates. Current systems that utilize Global Positioning Satellites (GPS), inertial measurement units (IMUs), and digital terrain databases (DTED) can return fairly accurate uncertainty estimates due to the well-characterized error sources of the system inputs. However, when computer vision-based algorithms are used to compute the geo-location of an object (e.g., if GPS is not available for some reason), accurate uncertainty estimates are not straight-forward to compute. For example, registration of the captured imagery to pre-existing reference imagery, feature tracking to enable vision-aided, GPS-denied navigation, or frame-to-frame image registration will all produce outputs with non-Gaussian and currently unknown uncertainties. This is compounded by the problem of outliers in both the inputs and outputs. While many algorithms have been developed to minimize the probability of outputs that are outliers, the probability is still non-zero and is not estimated with current approaches. The goal of this project is to develop the mathematical basis and algorithms for accurately estimating uncertainty when computer vision algorithms are used in a geo-location process. Both registration and vision-aided navigation applications are of particular interest in this project. Delivery of MATLAB or similar algorithm code is required.

Currently, many algorithms exist that utilize the Kalman Filter. However, the covariance estimates of the Kalman Filter are known to be under-estimates for non-linear systems (the inconsistency problem for simultaneous localization and mapping -- SLAM.) In addition, the assumption of a Gaussian distribution may of itself be inappropriate for the outlier results common in visual processing algorithms. While the field of robust statistics helps minimize the impact of outliers, it does not address the generation of statistically valid uncertainty numbers. Addressing these two issues will be the primary focus of this project.

Commercialization Potential: Accurate characterization of geo-location uncertainty will enable deployment of computer-vision based algorithms within the military and for civilian applications that require known uncertainties (e.g., civil surveying applications).

PHASE I: Develop a mathematical basis and algorithmic prototype for automatically computing uncertainty estimates of monocular visual SLAM, image-to-image registration, and/or image-to-map algorithms. Compare uncertainty estimates achieved vs. current state-of-the-art algorithms (e.g., Kalman Filtering, particle filters) using real imagery data. Evaluate statistical consistency of uncertainty estimates.

PHASE II: Expand mathematical basis developed in Phase I to more geo-location algorithms. Demonstrate statistically valid uncertainty estimates on several different algorithms used for geo-locating objects in aerial imagery, including monocular visual SLAM, image registration procedures, and cross-modality image registration. In addition, transition and demonstrate Phase I algorithms in real-time environment (i.e., with similar processing and time requirements as the geo-location algorithms themselves).

PHASE III: Test the algorithms developed in Phases I and II in operationally-relevant environments. Verify the efficacy of the developed algorithms and increase their robustness to enable deployment in operational systems.

REFERENCES:
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2. “Improved Fusion of Visual Measurements Through Explicit Modeling of Outliers,” C. Taylor, in Proceedings, 2012 IEEE/ION Position, Location, and Navigation Symposium (PLANS).

3. “Observability-based rules for designing consistent EKF SLAM estimators,” G. Huang, A. Mourikis, and S. Roumeliotis, The International Journal of Robotics Research, 2010, v. 29(5).

KEYWORDS: Georegistration, algorithms, uncertainty

AF131-158 TITLE: <u>Cetane Sensor for Remotely Piloted Aircraft (RPA) Propulsion Systems that Operate on Heavy Fuel</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To develop and demonstrate a Cetane sensor for RPA internal combustion engines (ICE) that operates on heavy fuel.

DESCRIPTION: A new generation of remotely piloted aircraft (RPA) engines has been under development for the last eight years. Many of the RPAs that the military currently uses were designed for nonmilitary purposes and many operate on aviation gas (Avgas). The military RPA community has been working to convert engines from gasoline to heavy fuels such as JP-5, JP-8 and Jet A for a one fuel in the field concept that allows the military greater logistics flexibility. The development of an improved Cetane sensor will provide a fast, reliable method to analyze fuels in real time to optimize the RPAs ability to meet mission requirements. The Cetane sensing capability will improve RPA on-station availability, overall capability, and avoid the costs associated with laboratory analyzes, shipments, or packaging that may not represent the fuel properties located in the field.

Diesel fuels such as Diesel #2 are manufactured with a required Cetane number. ASTM D975 specifies a minimum of 40. Most Diesel #2 in the U.S. is 42-45. The specifications for JP-5, Mil-DFL-5624, JP-8, Mil-DFL-83133P-8, and Jet-A, ASTM D1655, have no Cetane rating. Cetane is important for compression ignition engines, and has no affect on turbine engine performance, which is what these fuels were designed for. Using fuels with too low of a Cetane number in a diesel engine will result in a rough-running, hard-to-start, or a non-running engine. There have been a number of internal combustion (IC) engine programs started by the military services that are being designed to use heavy fuel. Some of these developments are for spark-ignited (SI) engines and some are for compression ignition (CI) engines. CI engines rely on Cetane as the property that gives a diesel engine the ease of igniting the air fuel mixture. The higher the Cetane number of the fuel, the more easily it combusts. The ability of the military to run both SI and CI engines on heavy fuels such as JP-5, JP-8 and Jet-A with optimal performance requires an ability to calculate the Cetane rating of the fuel as it is being used. Many of the new developmental RPA engines are being designed for direct injection. Therefore, the fuel injection system will be controlled by a computerized control system. This will enable the capability to change injection timing in near real time based on the Cetane number that is being determined and that data will be sent to the engine control system. This will allow engine performance to be optimized when using different sources of JP-5, JP-8, and Jet-A fuels.

During the Phase I effort, Cetane sensor concepts should be proposed that provide adequate performance in the measurement of Cetane for JP-5, JP-8, and Jet A. The sensor must be made small enough to be part of the RPA system and be able to make real time calculations of the Cetane properties of the fuel being utilized. Phase II will fully develop, fabricate, and demonstrate the system in a ground test environment with designs integrated into a RPA propulsion system. Phase III options should integrate the system into a new generation propulsion system to be used by the military and to test system performance with flight tests in an RPA mission environment. It is also appropriate to investigate methodologies that correlate engine performance measurements with Cetane values. Fuel detonation propensity, burning rate, and pressure developed are related to fuel characteristics and directly affect dynamic performance. Performance measurements can include, but not limited to, combustion pressure, timing measurements and engine dynamic torque measurements.

PHASE I: Demonstrate the feasibility of an innovative Cetane sensor in a small package through modeling, empirical, pragmatic, and chemical analyzes of the fuel. The sensor concept should include the size and weight estimation of the sensor and the expected performance. The sensor should have the capability to output the Cetane rating of the fuel to the RPA control system.

PHASE II: The Phase II effort will fully develop and fabricate the sensor system design from Phase I and demonstrate it in a ground-based environment. Ideally, the demonstration should use an in service or development engine that is aimed at the RPA environment. Different sources of fuel should be used for demonstration.

PHASE III: A Cetane sensor with the above characteristics could be highly marketable in the commercial sector to optimize the running of diesel engines for both optimum performance as well as decreased emissions.

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KEYWORDS: cetane, cetane sensor, unmanned aerial vehicle, remotely piloted aircraft, propulsion system, compression ignition engine, JP-8, JP-5, Jet-A

AF131-159 TITLE: Innovative Hybrid Power System for Increased Endurance Rapid Response Small Unmanned Aerial Systems (SUAS)

TECHNOLOGY AREAS: Ground/Sea Vehicles, Materials/Processes

OBJECTIVE: Develop a hybrid electric propulsion system to support a Rapid Response Small SUAS (< 30lb) capability. This requires fast dash (>150mph) while maintaining extended endurance (>15 hrs) on station and low acoustic noise operation.

DESCRIPTION: United States Forces currently have a need for a SUAS (<30 lbs gross take-off weight (GTOW) in remote areas for a variety of functions, such as reconnaissance, surveillance, targeting and acquisition (RSTA) in support of convoy operations due to the capabilities that these systems offer. For non-military use, this type of SUAS can fulfill multiple roles where there is currently a significant need, such as for border patrol and emergency responders, quick assessment of forest fires in remote areas, intercept/surveillance of suspicious boats approaching the coastline, etc. Unfortunately, for quick response applications, currently-fielded SUASs in this size class either do not have both the fast response times or the on-station endurance necessary to complete the mission (i.e., 44 lbs GTOW SUAS with dash speed limited to 90 mph, endurance limited to 10 hrs time-on-station @ 60 mph). Industry is working to develop all-electric SUASs that can achieve cruise speeds in excess of 150 mph; however, much research is still needed to extend their endurance (with integrated payload) and to demonstrate the system's utility for both military and non-military applications.

The goal of this topic is to develop an all-electric (i.e. fuel cell hybrid with turbogenerator, etc.) propulsion system to support a rapid response (55+ mph loiter speed; 150+ mph dash speed) <30 lbs GTOW SUAS capable of providing ‘eyes-on-target’ within 2-3 minutes over a 6-mile flight radius with low acoustic noise operation. The SUAS propulsion system should enable an endurance of at least 15 hours (> 15hr threshold, >25hr objective) and support a 2+ lb payload, which could include (but is not limited to) a gimbal-mounted stabilized EO/IR camera, with sufficient power reserved to operate the payload during loiter. User requirements sometimes dictate that SUASs operate in environments with high winds (35 knots threshold, 50 knots objective) and/or low temperatures (down to -30oF) at high altitudes (up to 12,000 ft Mean Sea Level (MSL) threshold, 25,000 ft MSL objective). Additionally, the operation of the propulsion system requires a low acoustic signature (i.e. acoustically non-detectable at the AV mission altitude, typically no greater than 1,000 ft AGL). The SUAS propulsion system designed under this topic shall demonstrate a path to operate in these environments. Furthermore, since the SUAS of this size class will be directed towards small team operations with portability and transportability in mind, the power system should operate on a fuel consistent with a low logistics footprint. A sample mission may include: Take-off/dash to target area, loiter for an extended duration (>15 hrs) while providing sufficient power for payload operation (e.g. 10% loiter power reserved for payload), return/dash to initial launch position. In addition to the design, key technical challenges/performance limitations shall be outlined. A plan shall be proposed as to how technical challenges can be overcome and requirements met to achieve flight objectives.

PHASE I: Design an advanced power system (e.g. fuel cell/turbogen hybrid) capable of operation on a SUAS with the payload, achieving total GTOW <30 lbs. Define performance parameters/interface constraints. Demonstrate feasibility through modeling & simulation and/or bench tests that the system has sufficient power/energy-density to meet design metrics, using above sample mission as baseline.

PHASE II: Develop advanced power system with a focus on integration into SUAS. Obtain baseline data from selected platform to verify power system sizing and use as performance comparison. Demonstrate that SUAS system is capable of producing sufficient power-to-weight ratios for adequate climb and dash performance, and able to attain program endurance metrics in a simulated operational environment (threshold). Flight test the SUAS to verify performance in an actual operating environment (objective).

PHASE III: Military applications include intelligence, surveillance, and reconnaissance (ISR), target tracking and acquisition. Commercial applications include border patrol and search and rescue for emergency responders.

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KEYWORDS: Quick response RPA, hostile fire detection, Remotely Piloted Aircraft , RPA, Small RPA, small unmanned aerial system, SUAS, UAV, RPA, electric power system, fuel cell, hybrid power system

AF131-160 TITLE: Advanced Propulsion and Power Concepts for Large Size Class Unmanned Aerial Systems (UAS)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate more efficient and reliable propulsion and power systems for large (10,000 lb class) RPAs to improve capability over existing conventional propulsion and power generation systems.

DESCRIPTION: Tactical requirements for unmanned aerial systems (UASs) exceed current capabilities for performance, reliability, maintainability, and supportability. Mission requirements such as extended endurance, increased power for auxiliary/sensor systems, and low altitude, low speed maneuverability are becoming paramount. Specifically, in the 10,000 lb class of vehicles, which usually includes only ground launched systems, these capabilities are not currently optimized with either electrochemical energy storage-based propulsion concepts, or with existing petrochemical engine-based propulsion concepts. Electrical power required for advanced payloads has increased dramatically. The objective of this topic is to investigate advanced propulsion and power concepts that span the potential spectrum from pure petrochemical to full electrical that can meet the current and projected future needs of large RPAs. Current RPA propulsion and power systems are sized to provide enough power and speed for takeoff requirements, leading to systems which operate inefficiently at other operating conditions. In addition, current systems can be noisy, which may limit RPA operational effectiveness. Fully electric based systems are quiet, but have issues with power density and energy storage capacity. Fuel cell-based systems could provide a very efficient energy source, but tend to be limited in the amount of power provided for larger RPAs. Batteries are limited by their energy storage capacity, unless they can be charged during operation by another energy source. A hybrid approach could enable users to take advantage of the quiet, efficient operation of electric-based propulsion while also taking advantage of the power density of current engines. All concepts will have to meet the different operational conditions of large RPAs, which should include full power takeoff and dash modes for 10 percent of mission duration and part-power cruise and loiter conditions for 80 percent of mission time as an example. Loiter mode should include segments of quiet operation (e.g., 10 to 30 percent of total mission duration) and segments of increased electric payload power draw. Key capabilities include the ability of systems to operate with heavy-fuel (JP-8, diesel); possible dual operation of electrical and petrochemical engine components to additively produce peak propulsive power; the ability to regenerate a rechargeable electrical power storage system during cruise conditions; the ability to shut-down the engine and run in electric-only quiet propulsion mode, if applicable; the ability to restart the engine as applicable; and the ability to provide electric power to a number of payloads.

During the Phase I effort, concepts should be developed that provide adequate power for propulsion and sensor payloads, as well as have a decreased weight over present single-power concepts.  Key capabilities will be to achieve mission loiter equivalent to present systems, i.e., mission endurance of 12 to 16 hours as a minimum.  Phase II will develop, fabricate, and demonstrate the system in a ground test environment.  Phase III options should plan to integrate the enhanced propulsion system into an airframe and demonstrate the performance of the system with flight testing in a RPA mission environment or demonstrate the capabilities in a ground test environment that can simulate mission conditions such as altitude and temperature differentials.

PHASE I:  Demonstrate the feasibility of an innovative approach for advanced power and propulsion concepts through modeling, empirical, and pragmatic analysis.  The analysis should include the effects or requirements driven by vehicle, subsystems, payloads, and all other ancillary components of the power and propulsion system.

PHASE II:  The Phase II effort will fully develop and fabricate the system design from Phases I and II and demonstrate the system in, at least, a fully representative ground-based environment.

PHASE III:  Military Application:  Performing intelligence, surveillance and reconnaissance, targeting and target acquisition missions.  Commercial Application:  Law enforcement, Homeland Security and emergency service RPA performing intelligence, surveillance, search and rescue, and disaster relief missions.

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KEYWORDS: remotely piloted aircraft, hybrid propulsion system, heavy fuel engine, energy storage, fuel cell, battery

AF131-161 TITLE: <u>Improved Reaction Models for Petroleum and Alternative JP-5/8 Fuels</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE:  Develop and employ accurate combustion reaction mechanisms for logistic hydrocarbon fuels with vitiation and/or exhaust gas recirculation (EGR).

DESCRIPTION:  The Department of Defense has two goals for future use of fuels in the battle space.  The first is to operate with a single fuel in the battle space to simplify logistics and supply concerns.  Currently that fuel is JP-8/JP-5.  The second is to develop alternative fuels for the battle space that are derived from more secure sources.  These alternative fuels, while meeting the JP-8 specification, can have properties that vary widely.  Recent research at Air Force Research Laboratory indicate that variations in Cetane Number and aromatic content of JP fuels, while meeting the JP-8 specifications, significantly impact combustion in gas turbine engines.  Cetane number of the fuel also dictates weather the fuel will be acceptable for use in diesel engines.

Vitiation, or EGR, is the combustion of fuel with a reactant stream that has previously undergone the combustion process but still has sufficient oxygen to sustain further reaction. In a gas turbine engines the inter-turbine burner and/or augmentor is a secondary combustor downstream from the main combustor and either between or behind the turbine respectively.  These combustion systems increase the enthalpy of the core stream further through the reaction of available oxygen.  For highly supercharged diesel engines with low compression ratios, EGR is sometimes used to improve the performance of the engine.  In all of these cases the air in the reactant stream has undergone reaction with fuel once resulting in reduced oxygen and increased $CO_2$, $H_2O$, and $NO_x$.

The effects of vitiation or EGR on secondary combustion are significant [Fuller et al, Risberg et al., Kalghatgi]. The $CO_2$, $H_2O$, and NOx in the EGR/vitiation reactant stream influence both the progress of the chemical reactions and the laminar flame speed of the combustion. The influence of these species on combustion and flame speed varies widely with pressure. These effects are non-monotonic in pressure. Very little work on the interaction of EGR, especially NO, and JP-8 at typical diesel engines conditions has been reported in the literature.

In order to fully understand and properly implement EGR in the diesel cycle and maintain stable combustion in gas turbine engines, it is necessary to have accurate, validated models for the chemical kinetics of the ignition, combustion process, and flame speed under vitiated conditions at various pressures. Specifically, the chemical kinetic implications of exhaust gas interaction with paraffinic and aromatic components on the overall ignition of JP-8 must be examined. In addition, most combustion kinetic mechanisms that are intended for use with jet fuels have been primarily developed for reactions with clean air, and have not been validated for vitiated oxidizer conditions, especially at the conditions encountered in diesel engines and interturbine burners.

Desired is an improved chemical kinetics model that accounts for vitiation over the pressure and temperature range of diesel engine, interturbine burner, and afterburner operation. The model should also be validated using ignition delay, flame speed, and species time history data for the best possible accuracy for use in combustion simulations. Improved models should be easily implemented into commercial combustion codes. It is desired that the software and associated documentation be delivered at the end of the Phase II effort for additional evaluation by U.S. Government personnel.

PHASE I: Demonstrate feasibility for improvement of current chemical kinetics models for the inclusion of exhaust gas/vitiation over a wide range of pressures and temperatures. Model shall have the ability to predict major species, laminar flame speed, and ignition delay time measurements over the range of conditions of interest for diesel engines, interturbine burners and gas turbine augmentors.

PHASE II: Further develop the kinetics model to predict flame speed, ignition time and major species in a vitiated environment over a range of pressure and temperatures and pressures relevant to diesel and gas turbine engines and augmentors. Validate the model to simultaneously match flame speed, ignition delay time and major species. It is desired that the software and associated documentation be delivered at the end of the Phase II effort for additional evaluation by U.S. Government personnel.

PHASE III: Potential applications include numerous commercial codes used for reactive flow modeling. Potential markets include commercial diesel engine manufacturers as well as furnace and boiler manufacturers.

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KEYWORDS: vitiation, exhaust gas recirculation, detailed kinetics

AF131-162 TITLE: Improved Fidelity Predictions for Resonant Stress in Turbine Components

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To improve physics-based design systems for turbine-component durability by providing a means to predict both aerodynamic forcing and aerodynamic damping in relevant geometries via a single high-fidelity calculation.

DESCRIPTION: Turbine engine performance increases result in substantial savings in aircraft life cycle costs. Thrust specific fuel consumption (TSFC) decreases with increases in both turbine inlet temperature and the overall pressure ratio of the cycle, but this combination often results in decreased turbine durability. Turbine components are subjected to exceptionally harsh environments and failure due to high cycle fatigue is common in the development of new engines. Resonant stresses that lead to fatigue failure can arise as a consequence of the interaction between a turbine blade and airfoil wakes, potential fields, and/or shocks that can travel downstream and/or upstream through the engine. Turbine airfoil surfaces constantly encounter fluctuating flowfields induced by such flow structures. These can manifest as pressure fluctuations that impart time-varying forces that generate cyclic rotor vibratory stresses that can in turn reduce the life of the airfoil. Design methodologies are constantly being improved to predict these airfoil vibratory stresses, and computations of some level of fidelity are now performed in the design cycle at many companies. Additionally, the motion of the airfoil as it vibrates can act to reduce or increase the motion while at the same time affecting the force on the airfoil. The fidelity of predictions of this fluid/structural interaction is critical to making effective design decisions relative to flutter and/or the magnitude of resonant stresses prevalent in the airfoil. Accordingly, a decrease in the level of empiricism in resonant stress predictions would have substantial benefits to the development cost of future systems and components.

Typical practice for determining resonant stresses involves substantial simplification of the physics of the problem. For example, computation of aerodynamic forcing functions is usually performed assuming rigid components. That is, the fluid and solid models are assessed in an uncoupled manner. Additionally, aerodynamic damping is usually estimated based on past experience and only occasionally are aerodynamic damping calculations performed. On top of this, there are well known means of reducing aerodynamic forcing like asymmetric airfoil spacing that necessitate full-wheel unsteady aerodynamic analyses for accurate predictions of resonant stress. Often, empiricism or at best simple Fourier analysis is used to determine the design of an asymmetric vane ring. To this is added the geometric variation between components around the wheel that can increase or decrease the resonant stress experienced by the blade. So, an increase in the fidelity of physics-based design systems with respect to aeromechanical predictions is sought that will take into account the variability of turbine airfoils in operating engines as well as the nonlinear effects that airfoil motion has on aerodynamic forcing functions.

PHASE I: Demonstrate the feasibility of an improved physics-based analysis tool in accordance with the requirements stated in the description. A preliminary design of a turbine component accomplished with the analysis tool and a plan for experimental validation will be accomplished during the Phase I effort.

PHASE II: Fully develop, demonstrate, and validate the software tool proposed in Phase I. A demonstration will be conducted at the end of Phase II. It is desired that the software and supporting documentation be delivered at the end of the Phase II effort for additional evaluation by U.S. Government personnel. It is encouraged that the small business team with turbine engine manufacturers to ensure suitability of the tool for use in a commercial environment.

PHASE III: The code would be used by both commercial and military engine manufacturers to design airfoils for advanced demonstrator engines, and be adopted as standard work, thereby resulting in life cycle cost reductions.

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KEYWORDS: turbine, durability, high cycle fatigue, aerodynamic forcing, aerodynamic damping, lifing, thermomechanical fatigue, physics-based design

AF131-163 TITLE: Bearing Analytical Software Development and Validation

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Update and validate bearing analytical software with improved thermal and life models for bearings in critical applications such as gas turbines and engine related drive systems.

DESCRIPTION: The thermal management and rolling contact fatigue (RCF) life of bearings in modern turbine engines are increasingly challenged as engine speeds, loads, and temperatures are increased to meet improved cycle efficiency. This trend should increase for next generation turbine engines that improve fuel efficiency. Heat generation and life models in commercial-of-the-shelf (COTS) bearing analytical codes used in the gas turbine industry have not been updated in over two decades and are now inadequate to accurately predict bearing life and heat generation. Also, existing life models are unable to predict the rolling contact life of the next generation bearing materials such as Pyrowear 675 steel, nitride M50 and M50 NiL, and bearings operating with silicon nitride rolling elements. This program will develop improved bearing life and heat generation models to meet this requirement. Improved lubricant traction models will be developed to improve bearing heat generation analysis. Bearing life models will consider how the next- generation bearing steels and use of silicon nitride ceramic rolling elements contribute to bearing life. Lubricant traction, bearing heat generation, and bearing life models will be validated using experimental data. The new models will be integrated into a bearing analytical code currently used by industry to predict bearing performance. The bearing geometry, applied loads, rotational speeds and thermal environment will be used to define the bearing operating and boundary conditions. The analytical code will include all internal loads, kinematics, and lubricant properties to achieve accurate bearing life and heat generation prediction. The analytical code will have a PC graphical user interface (GUI) for input and output. Output will be summarized in tablature and graphical form for easy interpretation by the user. Potential bidders are highly encouraged to work with a gas turbine engine company to ensure the approach is relevant and for access to the latest bearing heat generation and life data. It is desired that the software and associated documentation be delivered at the end of the Phase II for additional evaluation by U.S. Government personnel.

PHASE I: Demonstrate the feasibility of the improved analytical code to effectively model current traction, bearing heat generation, and life data for a chosen bearing system. The improved model will be compared to state-of-the-art models currently in use.

PHASE II: Further develop the analytical software into a useable product and validate results with obtained experimental data for lubricant traction, bearing heat generation, and bearing fatigue life. Develop an effective GUI to assist users in ease of operation. An end of contract demonstration should be conducted for interested government personnel.

PHASE III: The small business will provide commercial availability of the analytical code to the aerospace industry for applications requiring high precision bearing designs, e.g., turbine engines, satellite gyroscopes, and rocket pumps. The technology has application for both military and commercial systems.

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KEYWORDS: bearing analytical computer code, bearing life prediction, bearing heat generation, bearing power loss, ADORE, SHABERTH, COBRA, traction modeling

AF131-164 TITLE: Real-time Tactical Aircraft Fuel Ullage Oxygen Sensor System for Inerting Operations

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Increase survivability of advanced tactical aircraft as protection against fuel tank explosion and lightening strike vulnerability throughout the flight envelope by using a real-time oxygen sensor measurement system for fuel-tank inerting.

DESCRIPTION: Higher levels of oxygen present in the air/fuel vapor space (ullage) of tactical aircraft fuel tanks increases risk of explosion and fire due to ballistics, lightning strikes, and other system failures. Oxygen content of this ullage must be controlled to levels of 9 to 12 percent by volume. In order to displace oxygen in the tanks, nitrogen-enriched air (NEA) from an inerting system, often called the Onboard Inert Gas Generation System (OBIGGS), is pumped into the fuel ullage. A real-time oxygen sensor system is desired for adaptive closed-loop feedback control of NEA from the OBIGGS pack in energy optimized aircraft. This will reduce the demands on the environmental control system when tanks are already inert. This reduction will enable more efficient use of engine bleed air for cooling flows for avionics, aircrew, electric power generator, fuel, and propulsion systems. Ideally, a fuel tank ullage oxygen sensing and monitoring system should also provide a real-time fuel tank temperature and pressure measurement for thermal management system calculations, determining liquid fuel thermal capacity remaining in the fuel tank.

Current sensors are applicable to cargo aircraft operating under different mission profiles. These current systems have not been fully matured and integrated into tactical aircraft systems, and are not fully environmentally qualified electronics units with appropriate aircraft interfaces. New generation sensor systems, to include the sensing probe and electronics unit (EU), must be redesigned and fully evaluated for current and next generation tactical aircraft needs, as well as integrated into the aircraft electrical and fuel inerting control systems. Emphasis should be placed on total system development.

The desired system will not only provide active control incorporating multiple sensor feedback in closed loop, but also provide feedback to the cockpit for pilot awareness. The complete sensor system must provide accurate, reliable operation over temperatures and pressures experienced in advanced tactical aircraft fuel tanks in the flight envelope, be intrinsically safe, and survive under shock and vibration loading during takeoff, landing, and mission profiles. Anticipated temperatures range for the sensor probe from -45°F to 215°F (the electronics unit must operate from -60°F to 160°F) and pressures range from atmospheric down to 50,000 ft in altitude. It must be lightweight (less than 5 pounds), durable, low cost, able to interface with aircraft electrical and control systems (IEEE 1394 "Firewire"), and must have low power consumption. The sensing probe must be compatible with fuel and fuel vapors. In addition, while not a critical requirement, if the sensing system is designed to incorporate a bulk fuel temperature/pressure sensing capability, it is highly desired that this be incorporated into a single compact unit, i.e., one sensor system versus two.

PHASE I: Design and demonstrate feasibility of a new generation oxygen sensing system for fuel tank inerting and lightning suppression at pressures and temperatures experienced within a tactical aircraft flight envelope. Control and operation of a feasible sensor system can be shown by laboratory investigations.

PHASE II: Complete full development of a production representative sensor system and demonstrate in a simulated relevant tank environment. Abbreviated testing of the sensor system under MIL-STD must be conducted and qualification testing of sensor interface must be completed. A full-scale, simple-to-operate working unit is desired for delivery to the Air Force at the completion of this program phase.

PHASE III: This technology is also directly applicable to commercial aircraft. It is encouraged to develop commercial partnerships for transition into commercial aircraft as well as with prime contractors to the military and their suppliers. An oxygen sensor system should be developed as an end product.

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KEYWORDS: oxygen sensor, fuel tank flammability, fuel tank inerting

AF131-165 TITLE: Aircraft Energy Management

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Demonstrate a subsystem control methodology to optimize aircraft power generation, distribution, utilization, and associated thermal management based upon potential tactical vehicle operational power requirements and environmental conditions.

DESCRIPTION: The Integrated Vehicle Energy Technologies (INVENT) program was initiated to demonstrate the use of adaptive subsystems (robust electrical power system, adaptive power and thermal management, and high performance electric actuation) to optimize use of energy by advanced more-electric airframes across multiple mission segments. It is anticipated that this energy optimization approach can result in considerable reductions in parasitic fuel burn compared to the traditional stressing case approach used in traditional military aircraft design while ensuring that the aircraft meets performance requirements over the entire mach/altitude mission envelope. In order to accomplish these goals, it is essential that multiple vehicle systems be designed and operated in an integrated framework allowing for dynamic and on-demand energy utilization based upon varying vehicle demands.

A major challenge to the implementation of adaptive aircraft subsystems is development of a robust vehicle-level control system. This master control system must monitor the overall energy use of the platform and dictate control recommendations to the lower-level subsystems necessary to maximize range based upon specific operational demands required from the aircraft (e.g., best altitude/best mach, combat-specific operations, etc.). Successful control strategies require an objective function that allows for variations based upon changing mission requirements such that energy optimization can still occur in a local environment which may be suboptimal compared to ideal mission conditions. Additionally, stressing mission cases such as the use of high energy, low-duty cycle peripherals or sustained supersonic, low-altitude operations must be accommodated.

To minimize total mission energy usage for given sets of potential missions, the energy management unit must passively attempt to determine the anticipated performance desirements based upon instantaneous flight conditions. Using a known set of subsystem needs based upon the energy manager's best guess of the pilot's desired operational mode (max range, max performance, etc), the vehicle energy manager must use its time-dependent value function to prescribe a given set of performance objectives to individual subsystems. This energy manager would then seek to minimize the energy consumption within this set of objectives and recurse in a time-step consistent with the response capability of the subsystems. It is understood that while total energy or fuel burn would be the primary value function driver, other factors such as thermal and power system capacity management, electrical power quality, subsystem priority, or other specialty considerations must be considered.

A significant consideration in the development of this vehicle energy management unit relates not only to the mathematical construct of this value function, but also to the individual mathematical relationships to each subsystem. It is anticipated that each energy management/subsystem relationship may require a different mathematical construct e.g. analytical, statistical/Boltzmann, rules-based, etc. Regardless, the complexity of these mathematically interdependent relationships present considerable challenges not only to the design of potential aircraft electrical and thermal architectures, but also to the control of each of these systems. While it is understood that insufficient data is available to explicitly define these relationships, the type of mathematics expected to be used and any associated control parameters must be established based upon the relative differences in the subsystem's time constants, gain, and relative priority.

PHASE I: Demonstrate the feasibility of an energy optimization approach to develop a control methodology of a representative tactical fighter architecture allowing dynamic operation of pertinent systems with the intent of maximizing range. Demonstrate specific mathematic relationships between vehicle systems which allow for dynamic optimization of performance and assess system performance benefits.

PHASE II: Utilizing either Government-provided or commercially-obtained subsystem and component dynamic toolsets, apply the control system developed under the Phase I to explore system configurations which can demonstrate improved performance against an established benchmark aircraft configuration. Perform some level of validation of this integrated modeling environment using available data sources. Provide an enhanced aircraft subsystem and control suite demonstrating viability of the control approach.

PHASE III: Phase III objectives include application of the developed control approach to a next generation tactical fighter, advanced mobility, or related platforms. Commercial applications include more electric aircraft and hybrid-electric automobiles.

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KEYWORDS: energy optimization, air vehicle optimization, aircraft thermal management, INVENT, vehicle energy management

AF131-166 TITLE: Scalable, Wide Bandgap Integrated Circuit Technology for Wide Temperature, Harsh Environment Applications

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop technology that advances the performance, reliability, and manufacturability of wide bandgap integrated circuit technology for applications from 300 °C to 500 °C.

DESCRIPTION: The very nature of fifth-generation stealth aircraft poses increased challenges when it comes to thermal management. Many of the complications that are due to thermal management issues affect electronics performance. The addition of electric actuation, as with the Joint Strike Fighter (JSF), adds further to the demands of electronic systems on the aircraft. Silicon carbide (SiC) power electronic devices (diodes and switches) are currently being used as part of the solution. SiC devices can operate at higher temperatures than their Si counterparts. This higher temperature rating leads to better reliability and makes heat extraction easier. Control circuitry, however, is still accomplished with Si-based electronics. Silicon-on-insulator (SOI) technology has been demonstrated as high as 300°C; but a rating of 225°C is common for commercial SOI components. Further increasing the temperature rating of control circuitry up to and past 300°C would allow collocation of power switches and their control circuitry in much higher ambient temperatures than currently attempted. The collocation of power devices and integrated circuits would reduce wiring, shielding, and cooling system demands and complexity. High-temperature integrated circuits (ICs) are also essential to the development of distributed engine control and smart sensors for turbine engine health management.

A logical candidate for a high-temperature IC material is the same SiC that is yielding success on the power device front. Progress has indeed been made in the development and demonstration of SiC integrated circuits. Integrated circuits based on 6H-SiC JFET technology have been shown to operate from -125°C to 500°C and demonstrated thousands of hours of continuous operation at 500°C. However, these logic circuits based on normally-on 6H JFETs suffered from long propagation times of over a micro second. ICs based on 4H-SiC bipolar junction transistors have been demonstrated at 355°C and have propagation delays around 10 nano seconds. SiC BJT circuits, however, are more difficult to fabricate and are very sensitive to process variations. Success has also been recorded for 4H-SiC n-MOSFET based ICs operating at over 400°C.

These results demonstrate that high-temperature ICs can be made out of SiC; however, much work needs to be done in order to bring this technology to the point where it has the reliability, complexity, and performance required for insertion into the above-mentioned wide-temperature aerospace applications. This research topic seeks technologies that improve the performance, scalability, and manufacturability of wide bandgap (in particular, SiC)-based ICs.

These advances may be (but are not limited to):
• Innovative circuit designs that better utilize current device technology.
• Advances in the design and fabrication of the basic IC building blocks (transistors, diodes, resistors, etc.).
• Technology that enables faster, more efficient logic architecture (complimentary logic design, for example).
• Fabrication advances that would enable scalability to a level suitable for ASIC or FPGA design.

While SiC remains the most likely solution the wide-temperature applications discussed here, solutions based on other technologies such as other wide bandgap materials and/or heterostructures are not excluded.

PHASE I: Demonstrate the feasibility of the proposed technology through fabrication, testing, and modeling and simulation of the basic IC building blocks operating from -50°C to 300°C. Modeling and simulation of design solutions based on previously demonstrated device technology may also suffice to show feasibility. A realistic, physics based roadmap to 350°C continuous operation must be shown.

PHASE II: Further develop the proposed technology and use it to produce an operational amplifier or IC of similar complexity that demonstrates the performance and scalability of the phase I technology. The circuit should demonstrate suitable functionality at temperatures up to at least 350°C.

PHASE III: Packaging, testing, and qualifying of critical IC component with broad applications to wide temperature aerospace needs.

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KEYWORDS: wide bandgap, silicon carbide, integrated circuit, high temperature electronics, logic gate, high temperature operational amplifier

AF131-167 TITLE: Thermal Interface Materials for Power System Components

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop technology to reduce thermal resistance between power components and cold plates; increase mechanical compliance due to thermal expansion coefficients; increase thermal cycles before degradation and ensure ease of workability.

DESCRIPTION: The stable and reliable operation of megawatt-class, high-temperature power electronics is critical for military aircraft operations. Emerging multi-switch power modules, based in silicon carbide (SiC) electronics, have increased operating temperatures to over 200 °C, leading to very high heat fluxes from the components to thermal management systems (i.e., cold plate). Limitations of existing thermal interface materials, combined with high coefficient of thermal expansion (CTE) mismatches between the component and heat sink materials, results in higher temperature operation with commensurately reduced reliability. New thermal interface material technologies should be factors lower in thermal resistance than greases. At end of life, the thermal resistance of greases ranges from 0.05 °C–in2 /W to 0.1 °C–in2 /W on switch package size applications (~2 by ~4 inches) which lead to excessively high junction temperatures. A high mechanical compliance and the ability to be reworked/reapplied are also highly desirable. Solutions must also result in minimal change to existing manufacturing and assembly process, and demonstrate high potential for scalability.

New thermal interface materials must demonstrate improvements in cyclic durability at operating temperatures between -55 °C and 200 °C. It is estimated that improvements of 20 to 30 °C in peak junction temperature rise may yield a 3 to 5X improvement in cyclic durability, resulting in dramatic improvements to meet the objectives for robust electrical power systems (REPS) and aircraft thermal management.

PHASE I: Demonstrate improvements in thermal conductance by a factor of 4 over thermal greases and state-of-the-art (SOTA) interface materials, with the goal of reducing delta-T by 10 °C for a heat flux of 50 W/cm2. Thermal resistance should be measured by a standard technique (e.g., ASTM D5470). Demonstrate a functional interface prototype for power module component mounting to a cold plate.

PHASE II: Demonstrate improvements in thermal interface conductance by a factor of 10 over current SOTA for future high flux devices with marginal spreading. This would reduce the interface delta-T by about 30 °C for a heat flux of 100 W/cm2 throughout a -55 °C to 200 °C temperature regime. Demonstrate improved cyclic durability in a simulated power system operating environment. Uniformity of properties and performance over an expected power module base plate area of at least 25 cm2 is required.

PHASE III: Military application: Power system electronics and avionics systems comprised of high heat flux components. Commercial applications: Challenging applications such as telecommunications relay stations, data farms, and computing centers would benefit from interface materials with lower resistivity.

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KEYWORDS: power modules, computer processors, electronic components, full authority digital engine control (FADEC), high heat flux, Joint Strike Fighter (JSF), JSF, thermal interface materials

AF131-168 TITLE: Rotary Electromechanical Actuator for Next-Generation Thin-Wing Aircraft Flight Control

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a reliable rotary electromechanical actuator for next-generation thin-wing military aircraft flight control and validate its installation on thin wings.

DESCRIPTION: As smaller wing profiles become more prevalent in advanced tactical and fighter aircraft, the smaller wing size puts an increased burden on the actuation system for flight control surfaces. Current hydraulic-based actuation systems for flight control surfaces require space that makes it challenging to fit thin wing applications. In addition, hydraulic systems are always on, using power when not needed, resulting in lower efficiency and posing thermal management challenges for the aircraft power and thermal management system (PTMS). Rotary actuation that is located directly on the hinge line has the potential to provide compact installation and significant efficiency gains. This topic seeks advanced technologies of rotary electromagnetic actuation (EMA) systems that will meet thin wing installation requirements.

Some reference rotary EMA design requirements include: 1625 ft-lb minimum static hinge moment, minimum surface rate of 54 degrees per second against 710 ft-lb of rotational resistance, greater than 100 radians/s of actuation system open loop gain, minimum static stiffness of 1,000,000 lbf/in, minimum dynamic stiffness of 500,000 lbf/in, and operate in three modes (active, damped, and blocked/damped) while transitioning from one mode to the next within 100 milliseconds. The proposed innovative rotary EMA must fit in an installation envelope of approximately 83" x 14.5" x 5". Other performance characteristics such as jam tolerance, weight, efficiency, and thermal management should also be considered. Working with an airframer and/or an original equipment manufacturer (OEM) is encouraged to increase commercialization probability.

PHASE I: Demonstrate the technical and installation feasibility of the proposed innovation through analysis, design, and small scale experiment.

PHASE II: Fully develop, test, and demonstrate an operable prototype device that meets the requirements for a fighter-class military aircraft thin wing flight control surface in a laboratory environment. Emphasize the installation ability or the ability to integrate with the thin wing structure. Address system requirements, fault tolerance, structure integrity, and reliability issues.

PHASE III: Electromechanical actuators will have both military and commercial aircraft applications as more electric aircraft are developed and wing profiles become smaller.

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KEYWORDS: rotary actuator, rotary EMA, thin wing, flight control surfaces, fault tolerant

AF131-169 TITLE: <u>Robust Cryogenic Compatible Turbo-machinery and Liquid Rocket Engine coatings</u>

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Demonstrate feasibility of proposed coating technologies in cryogenic liquid rocket engine environments.

DESCRIPTION: In order to enable greater launch capability at significantly reduced operating cost, the Air Force is developing domestic technology for highly reusable oxygen-rich staged combustion hydrocarbon engines. These engines present unique operating challenges, particularly in their turbomachinery. The turbomachinery is highly mechanically loaded while exposed to 8000 psi, 1400 R and oxygen-rich gasses. While monolithic materials have been developed for this application, to date, they have only been partially successful and are extremely expensive. An alternative approach would be to develop a robust coating technology which is able to survive the environment for the 50 launch cycles between overhauls desired for a next generation launch system engine.

Novel approaches are desired to develop robust coatings for use in the high temperature, high pressure, oxygen-rich environment of proposed upcoming oxygen-rich staged combustion liquid rocket engines. While coatings have been investigated previously, for example on the Air Force Research Laboratory (AFRL) Integrated Powerhead Demonstration Program, they do not meet the long-life requirements necessary for this type of reusable system. Similarly, while coatings have been successfully applied to aircraft components, those materials have not yet been successfully demonstrated in the more demanding rocket engine environments.

Critical issues that must be addressed include: Ability to withstand the requisite environment, including not only chemical and thermal but also the high and low cycle fatigue necessary to achieve a 50 mission life between overhauls; compatibility with and bonding to the substrate material(s); and manufacturability. If applicable, processes for removing the material for part refurbishment, repair of lightly damaged coatings, and methods for non-destructively assessing the condition of the coating can also be addressed.

Since the cost of testing in the requisite environment is prohibitive under a SBIR program, it is expected that some demonstrations of the feasibility of the materials, particularly in Phase I, will be achieved through a combination of sub-scale hardware, analysis, similarity, or other approaches. While this is acceptable, clear linkage between the proposed demonstrations and the desired properties is necessary, and will be a critical point of evaluation. As much as possible, direct demonstrations in the relevant environment are encouraged.

PHASE I: Demonstrate the feasibility of the proposed material/coating system to survive in an environment representative of a reusable oxygen-rich staged combustion engine turbine. Demonstrations may include analysis or similarity, however clear linkage between any demonstration and the representative environment is critical.

PHASE II: Demonstrate and mature the proposed material by manufacture of a representative test article to demonstrate manufacturability and test the article to show survival in the oxygen-rich staged combustion environment.

PHASE III: The coatings will be most applicable to the newest generations of turbopumps and other rotating equipment in rockets as well as liquid rocket engines.

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KEYWORDS: turbomachinery, coatings, cryogenic, staged combustion, oxygen, LOX

AF131-170 TITLE: Compact High Current Molecular Atomic Particle Beam Generator

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Demonstrate the design of a micro-scale, ultra-compact, high-efficiency and massively scalable technology to create a high-velocity beam of atoms or molecules.

DESCRIPTION: A high performance and ultra-compact design of a space propulsion system is one of the most important developments required to meet many of the future needs for military space. In particular, the rapid progress in nanotechnology and multiple fields of micro-scale manufacturing technology has allowed the design of increasingly smaller sensors and electronic devices, and the consequent reduction in satellite size and weights. Further advances in the utilization of highly-compact space platforms depends on the developments of commensurate thruster technologies. The recent advances in fluid flow control and sensors (“lab on a chip”), combined with nano-structured materials and techniques used in the semi-conductor industry provide an opportunity to develop an integrated micro- or nano-thruster, i.e., “accelerator on a chip”. The design should be able to accelerate the propellant up to 10^6 m/sec (or about 50/100 keV for argon propellant). The successful design should attempt to fully integrate the propellant management system and power processing with the acceleration/thrust-producing unit. A design that also incorporates all or most of the power generation sub-system is also desirable. An example of such an approach is a pyro-electric material, although other advanced materials and physical properties can be considered. The ability to take full advantage of massively parallel, mass-produced fabrication is essential and the effort should clearly provide a convincing path towards a high degree of scalability. While the proposed effort can be limited in developing, manufacturing and testing a single unit, theoretical arguments and/or numerical simulations can be used to justify the path to larger-scale units, thus eventually allowing operating power ranges from Watt to kilo-Watt.

PHASE I: Demonstrate the feasibility of an approach through software/hardware simulations to meet topic requirements. While nanotechnology-based designs offer promising solutions, other approaches are also encouraged.

PHASE II: Fabricate a prototype unit to fully demonstrate the Phase I concept within a laboratory environment. Demonstrate that the system meets defined requirements with the exception of reduced total power levels. It is desired that the Phase II prototype be delivered to the Government for additional evaluation by laboratory personnel.

PHASE III: While the emphasis is propulsion, the technology could be adapted for other military purposes such as sensors. A potential commercial use could be found in high-precision manufacturing, similar to laser-processing, but possibly with wider applications.

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KEYWORDS: space propulsion, accelerator, molecular beam, atomic beam, particle beam

AF131-171 TITLE: <u>Hypersonic Propulsion: Enhancing Endothermic Fuel Technology</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Enhance or increase the capabilities of scramjet-powered hypersonic systems through the development of advanced endothermic fuels, fuel additives, catalysts or fuel cooling concepts for high-speed propulsion systems.

DESCRIPTION: Hydrocarbon-fueled supersonic combustion ramjets (scramjets) are expected to operate from Mach 3.5 (or lower) up to Mach 7 or 8. Scramjet engines are categorized into three general sizes: small-scale (nominal air flow of 10 lbm/s), mid-scale (nominal air flow of 100 lbm/s), and large-scale (nominal air flow of 1000 lbm/s). Recent efforts focus on mid-scale scramjets that need to operate over a broad Mach range, use minimal or no variable geometry, integrate with other propulsion cycles, and maintain thermal balance using only on-board fuel as a heat sink without significant losses to integrated system performance.

The basic design strategy for cooling of scramjet combustors is fuel-cooling of metallic walls. The combustor walls are typically constructed of integrated heat exchanger (HEX) panels. Fuel is passed through coolant channels adjacent to the heated surfaces to absorb heat, prior to injection into the combustor. The X-51 program represents the current state of the art for scramjet engine technology and can be used as a reference point. The engine has a regeneratively cooled structure using endothermic JP-7 fuel to extract heat from the engine walls prior to injection of the heated fuel into the combustor.

The upper Mach capability of a hypersonic propulsion system is currently limited by the ability to balance the structural cooling requirements with the available thermal capacity of the fuel. While the development of higher temperature materials, that will require less cooling, is already under way, it is important to acknowledge and pursue the opportunity for enhancement of the thermal capacity of fuels used in hypersonic propulsion systems. The high energy and volumetric density of liquid hydrocarbon fuels makes them attractive for high-speed propulsion applications. Furthermore, the endothermic reactions that occur during thermal decomposition of a hydrocarbon fuel can be exploited to provide heat sink in addition to what is available through the sensible heating of the fuel.

The maximum fuel temperature is limited by the formation and accumulation of carbon deposits, often referred to as coking, which is detrimental to the performance of both thermal management and fuel injection systems. Methods to increase the temperature at which coke forms; to promote the onset of endothermic reactions at lower temperatures; and to minimize or eliminate the formation, deposition and accumulation of coke all have a positive influence on the total thermal capacity of the fuel.

Some possible areas for proposal focus include: alternate fuels or fuel blends, tailoring chemical compositions for endothermic reactions, fuel processing technologies, catalyst development and application, additive development and application, innovative HEX design concepts, coke mitigation techniques, and so forth. Proposals may include any number of the areas identified and are by no means limited to the focus areas mentioned herein.

Proposals in response to this topic may either be computational or experimentally focused. Note that there is not expected to be any government-furnished equipment (GFE) required to perform a Phase I effort and proposals should not assume equipment or facility is to be furnished at no cost.

PHASE I: Demonstrate the feasibility of an advanced fuel concept to increase the capabilities of scramjet systems. This may be done via subscale testing, numerical analysis, simulations, or other means. Perform detailed numerical analysis or subscale testing of the proposed concepts and assess the impact of the concept and identify a path for application of the enhancing technology.

PHASE II: Fully develop the concept developing during the Phase I effort. Develop a test plan and associated test rigs to demonstrate improved performance versus the baseline technology in a laboratory environment. Provide engineering systems analysis for developing larger and broader operating ranges for scramjet systems. Fabricate and evaluate prototypical devices, hardware or test rigs to confirm Phase I predictions at an acceptable scale.

PHASE III: The advanced fuel will have applications in high-speed military systems, as well as future high-speed commercial applications.

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4. Castaldi, M., Leylegian, J., Chinitz, W., Modroukas, D., "Development of an Effective Endothermic Fuel Platform for Regeneratively-Cooled Hypersonic Vehicles," AIAA Paper 2006-4403, July 2006.

5. Billingsley, M., "Thermal Stability and Heat Transfer Characteristics of RP-2," AIAA Paper 2008-5126, July 2008.

KEYWORDS: hypersonic, scramjet, propulsion, high speed, space access, thermal management, endothermic fuel, catalyst, hydrocarbon fuel, heat exchanger, regenerative cooling, fuel additives, fuel cracking, fuel coking, pyrolysis

AF131-172 TITLE: Frequency Domain-based Electrical Accumulator Unit (EAU)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Analyze the frequency content and demand of emerging More Electric Aircraft and develop a Line Replaceable Unit capable of providing the high-frequency power requirements. The device will help source peak power demands and provide bus stabilization.

DESCRIPTION: The advancement to more-electric aircraft (MEA) has resulted in an increased focus for electrically-driven utilities, including flight critical actuation. In addition to these new loads, advancements in radar systems have increased both the continuous and peak electrical power demand from the power system. For these applications, uninterruptible and clean electric power is an essential requirement. Emerging MEA use multiple energy sources to meet specific aircraft power demands under all expected flight conditions, including actuator peak and regenerative energy demands, power and thermal management system (PTMS) electrical starting demands, active electronically scanned array (AESA) radar systems, and emergency power demands. The characteristic switching dynamics of these loads create very large rate of current change (dI/dt) events. The sharp current rise implies increased frequency content of the power delivered to the load. The repeated sourcing of this high frequency content may lead to unexpected system performance, including diminished power component reliability, distribution system lifetimes, and filter network performance. The electrical accumulator unit (EAU) is a recently-developed technology designed to work in parallel with the main aircraft generator. During intervals of heavy peak current demand, the EAU sources the majority of the current to the load. Therefore, the generator is used more as a source of average current with the EAU sourcing the peaks. An alternative approach is sought in for this research. A frequency-domain approach to designing an EAU will include the device sourcing the highest frequency components of the current, with the main aircraft generator sourcing the lower frequency current. The goal of this program will be to determine the frequency bandwidth performance desired, and build a Line Replaceable Unit (LRU) that sources the required current. Key to the success will be advanced power electronic topologies and controls as well as advanced energy storage devices. In addition, frequency domain EAU could provide simplified means of integrating prognostics and health management (PHM) algorithms into the power system. Innovative ideas are sought to understand the frequency content and demand of emerging MEA, and to develop a LRU capable of providing these high-frequency current requirements.

PHASE I: Demonstrate the feasibility of frequency-domain-based EAU to meet the requirements above. Define the conceptual design and predict the performance of the proposed design through analysis, preliminary modeling, simulation and/or small-scale testing. The proposed concept should be scalable and flexible to support various mission applications.

PHASE II: Develop the detailed design and fabricate a prototypical device or hardware demonstration to be tested in a laboratory environment. Models and/or simulations should be validated by demonstrations which fully capture the relevant physics. A clear definition of failure modes would be expected as well as the ability to meet required operational lifetimes.

PHASE III: This technology may have application in future commercial and military aircraft. Therefore, a production program will identify a potential transition platform and will develop necessary detail specifications for the completed LRU.

REFERENCES:
1. INVENT Modeling, Simulation, Analysis and Optimization; AIAA-2010-287, 48th AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition, Orlando, Florida, January 4-7, 2010.

2. Integrated Aircraft Electrical Power System Modeling and Simulation Analysis; 2010-01-1804: Power Systems Conference, November 2010, Fort Worth, TX, USA, Session: Modeling, Simulation, Analysis & Control.

KEYWORDS: more electric aircraft, electrical accumulator unit

AF131-173 TITLE: Combustion Enhancement of Liquid Fuels via Nanoparticle Additions

TECHNOLOGY AREAS: Materials/Processes, Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of

foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Demonstrate and quantify the impact of nanoenergetic particle addition to propulsion-system fuels. Optimize particle size, passivation and loading with a focus on engine performance and initial transients.

DESCRIPTION: Changing from micron-sized to nanosized energetic particles increases the reaction times and decreases the ignition delay times of the particles. In some cases improvements of several orders of magnitude can be achieved. These unique properties of nanoenergetic particles could be used to enhance the energy density of fuels used in propulsion systems. When mixed with traditional fuels such as JP-8 or RP-1 it is hypothesized that performance of turbine (fuel consumption / time on target) and rocket (ISP) engines could be improved as could the start-up transients. To date, however, such improvements have not been demonstrated and quantitative predictions have not been validated. Recent improvements in understanding the ignition and reaction mechanisms of dry nanoparticles (i.e., particles on their own without fuel added) as well as use in solid rocket motors have continued to highlight potential engine improvements and are enabling more in-depth studies at ever-more-realistic conditions. Yet, investigations of the behavior of wet nanoparticles is lacking, and the effect of the liquid on the energy release, burning rate and energy transfer speed of fuel-nanoparticle mixtures is not understood. These must be quantified to assess the efficacy of this approach to increasing the performance and start-up transients of engines. Beyond the general question of efficacy, implementation of nanoenergetic particles in combustion systems will involve optimization of particle type, size and loading; a mixing technique or demonstration that the particles remain in suspension; and perhaps alterations to current injectors to accommodate and atomize the multi-phase flow. Demonstrate the feasibility of nanoparticle additions to increase the energy density of propulsion fuels. Quantify change in combustion energy, reaction time, and/or ignition of baseline propulsion fuel (e.g., JP-8 or RP-1) versus improved fuel. The effect of particle size, droplet size, particle type, and any passivation layers should be considered along with enhancement as a function of particle loading, particle lifetime, changes in injector lifetime due to erosion and ability to maintain well-mixed conditions. Assessing all optimization parameters may be beyond the scope of this work, and emphasis will be placed on the enhancement as a function of particle size, type and loading, the impact and need for passivation layers and particle lifetime within an engine. Although aluminum nanoparticles have been extensively studied, this topic is not limited to the investigation of this single particle type. In addition to improving rocket and turbine engines, this work may be important for developing fuel additives to alter combustion products (potential reduction in harmful emissions).

PHASE I: Demonstrate the feasibility of nanoparticle additives to improve the performance of propulsion system fuels. Quantify change in combustion energy and/or reaction time of typical propulsion fuels (e.g., JP-8 or RP-1) with the addition of nanoenergetic particles. The effect of nanoparticle size, droplet size and any passivation layers should be considered. Particle type may also be considered.

PHASE II: Fully develop and optimize the improved fuel additive and demonstrate/quantify the enhanced performance for propulsion applications within a laboratory environment. Optimization parameters should include performance improvement and initial transients. Initial analysis for future operational transition should be considered such as engine lifetime effects, ensuring well mixed fuel, environmental/safety considerations, storage, and other such issues.

PHASE III: Quantification, optimization and modeling of the effects of nanoparticles addition to fuels will enable improvements in rocket and air-breathing engines. Improvements may include increased performance or improved ignition and start-up transients. Improvements may be made in civilian jet engines.

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1. Jones, M., Li, C.H., Afjeh, A. and Peterson, G.P., “Experimental study of combustion characteristics of nanoscale metal and metal oxide additives in biofuel (ethanol)”, Nanoscale Research Letters, Volume 6, Number 246, 2001. Doi: 10.1189/1556-276X-6-246.

2. Levitas, V.I., Dikici, B. and Pantoya, M. L., “Towards design of the pre-stressed nano- and microscale aluminum particles covered by oxide shell”, Combustion and Flame, Volume 158, Issue 7, July 2011, Pages 1413–1417. http://dx.doi.org/10.1016/j.combustflame.2010.12.002.

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KEYWORDS: rocket propulsion, air breathing propulsion, nanoparticles, nanoenergetics

AF131-174 TITLE: Enhanced Multi-wall High Pressure Turbine Blade Architecture

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To enhance the design of small turbo fan engine high-pressure turbine (HPT) blades for improved turbine life and validate design improvements through design analysis and testing.

DESCRIPTION: Next generation military unmanned aircraft whose propulsion systems are in the 15,000 lb thrust class, have a need for lower thrust specific fuel consumption (TSFC) and higher power-to-weight ratio that exceeds the capability of the state of the art in this thrust class. Improvements to engines in this thrust class support the warfighter capabilities and help reach the Versatile Affordable Advanced Turbine Engine (VAATE) III Program goals of reduction in TSFC by 35 percent, and increased power-to-weight ratio by 80 percent, and reduced cost by 55 percent of the entire propulsion system.

There is a significant body of knowledge on enhancing HPT technology to improve TSFC and power-to-weight ratio for large and very small turbofan engines. The challenge in enhancing performance is to increase HPT inlet temperature and reduce tip clearances. Both of these increase power density, and reduce SFC. Increased HPT inlet temperature, though, creates challenges for HPT durability. Scaling is the key issue for this class of turbines.

Heat transfer in the HPT is a function of Reynolds number and momentum ratio. As the Reynolds number decreases, so does the ability to effectively cool the HPT. It is difficult to simply geometrically scale turbine cooling strategies in the same fashion that the engine is scaled for thrust and fuel consumption because as cooling hole size decreases discharge coefficient (Cd) decreases nonlinearly. Decreased Cd requires increased pressure drop to cool the HPT, affecting efficiency. Further, the primary metric for cooling is blowing ratio. Direct scaling holes may increase film penetration, leaving the metal surface vulnerable to hot gases from the combustor. Skin thickness of the blades also decreases making it difficult to achieve film coverage from angled holes due to decreasing aspect ratio of the holes. Finally as the diameter of the HPT decreases tip clearances do not linearly scale, thus more care is required when designing the tip of the blade to ensure that the performance and health of the tip region is good.

New technologies are desired that provide enhancements in HPT inlet temperature and tip clearance capability while also maintaining/enhancing durability. Close collaboration with an original equipment manufacturer (OEM) of small gas turbine engines in the 15,000 pound thrust class is highly desirable to increase the probability of transition of the developed cooling and clearance technologies.

PHASE I: Demonstrate the feasibility of the innovative technology to improve HPT durability and SFC. Identify a baseline and develop concepts for improved durability of HPT blades with enhanced performance. Conduct CFD, heat transfer analyses and thermo-mechanical-fatigue analysis of candidate technologies and compare their performance to the baseline system.

PHASE II: Develop, fabricate, and test concepts analyzed in the Phase I effort. Assess the performance of the proposed HPT technologies and their impact on SFC and power to weight ratio. Assess the durability of the proposed technologies as compared to the baseline.

PHASE III: Transition developed technologies to commercial engine manufacturers and consider opportunities within the VAATE Phase II Program. Apply improved HPT technologies to commercial core technologies for regional business jet class of engines.

REFERENCES:
1. Vitt, P., Iverson, C., Malak, F.M., and Liu, J.S., 2010, "Impact of Flowfield Unsteadiness on Film Cooling of a High Pressure Turbine Blade," ASME Turbo Expo, Paper No. GT2010-22773.

2. Martin, E., Wright, L., and Crites, D., 2012, "Impingement Heat Transfer on a Cylindrical, Concave Surface with Varying Jet Geometries," ASME Turbo Expo, Paper No. GT2012-68818.

3. Ho, K.S., Urwiller, C., Konan, S.M., Liu, J.S., and Aguilar, B., 2012 "Conjugate Heat Transfer Analysis for Gas Turbine Cooled Stator," ASME Turbo Expo, Paper No. GT2012-68196.

KEYWORDS: enhanced, high pressure turbine blade, architecture, turbine life, TMF (Thermo-Mechanical Fatigue), CFD, heat transfer analysis, stress analysis, multi-wall, specific fuel consumption, durability, power to weight ratio

AF131-175 TITLE: Micro Airborne Relay Technology

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: To advance the state of the art in the capability to relay time space position information (TSPI) and data streams (including video).

DESCRIPTION: Open air range testing of munitions frequently takes place at locations beyond the line of sight of ground receiving stations (i.e.: over the horizon on water test ranges). At present, no commercially available, off-the-shelf miniaturized relay system exists for use in small Remotely Piloted Vehicles (RPV) to meet the following requirements:

Number of Data Streams Supported up to 12 including 4 HD Video feeds

Re-Transmit Power Level =5W

Minimum Signal Strengths Supported -100 dBm

Maximum Volume 9 cubic inches

Power Consumption 12 to 28V (from RPV)

PHASE I: Conduct a study and develop a technology concept that addresses the technical requirements. This concept development will address each of the parameters of interest to include what values could be attained.

PHASE II: Develop prototypes as a risk mitigation effort. Demonstrate a relay technology concept. The offeror shall develop viable demonstration cases by collaborating with the government or private sector entities.

PHASE III: Follow-on activities could be pursued by the offeror, namely to seek opportunities to integrate the demonstrated sensor technology into commercial test articles. Commercial benefits include improved competitive opportunities for providers of aerospace platform components and sub-systems.

REFERENCES:
1. "Micro-T Telemetry System", Rollingson, Larry L; Drake, Richard G., Lusk, Kenneth P, 20 Oct 1992.

2. "Near Real-Time telemetry Utilizing Satellite Communications", Maurer, Ricky L., 17 Aug 1995.

KEYWORDS: Telemetry Data Relay, Weapon Testing, Micro Relay

AF131-176 TITLE: Reusable Extended Artificial Light Source

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop a reusable light source to replace flashbulbs in order to photograph high speed test events. The reusable light source must meet or exceed specifications of currently used flashbulbs.

DESCRIPTION: Sled tracks are used for ground testing DoD weapon systems at various facilities around the U.S. Sled tests are conducted at these facilities at speeds up to 10,000 feet per second and can occur either in day or the night time configurations. When testing is conducted during night time operations, light sources are necessary to illuminate and photograph test events. Additionally, it may be necessary to add illumination in order to provide adequate lighting to record events when sub microsecond camera exposures are required. Currently, single use flashbulbs are used to provide illumination for photographing test events due to their intensity, overall emission of light in the visible spectrum, and extended duration.

The specifications for the currently used flashbulbs that the reusable extended artificial light source must meet or exceed are a minimum peak illumination of 6,000,000 lumens and a minimum duration of 0.03 seconds. The color temperature of the light source must be approximately 3,800 kelvin. The light source must be easily configurable such as stackable when more light is needed for sub-microsecond exposure times or to illuminate large areas. It must be portable as multiple photographic setups per day at various locations on the test complex are not uncommon. It must withstand overpressure experienced during explosive testing as well as withstand the shock environment generated by passing supersonic test weapons. Finally, the reusable light source must have a rise time that is repeatable within 10% to ensure it is a reliable light source for capturing critical photographic test and evaluation (T&E) data.

PHASE I: Phase I is to develop an extended artificial light source concept capable of replacing existing flashbulbs used to photograph high speed test events and assess the technical feasibility of the overall concept. Some component/system testing may be conducted to assist in the assessment. The final report should outline the various options, their strengths and weaknesses, and performance estimations.

PHASE II: Phase II should result in one or more prototype extended artificial light sources. Testing should be accomplished to validate the performance metrics outlined in the project description.

PHASE III: Military Application: sled tracks, wind tunnels and research labs using high speed photography for weapon system T&E. Commercial Application: high speed motion picture photography, destructive testing, large format photography, theatrical special effects, explosion research.

REFERENCES:
1. Lee, K. J. Design of a Flashbulb Firing Unit for Use with High Speed Cameras. Maribyrnong, Victoria: DSTO Materials Research Laboratory, Aug 1991.

2. Spindler, G. B. The use of Flashbulbs for Tracking Rockets. Valcartier, Quebec: Canadian Armament Research and Development Establishment, Oct 1961.

KEYWORDS: Flashbulb

AF131-177 TITLE: Angle of Incidence (AOI) Measurement Capability

TECHNOLOGY AREAS: Weapons

OBJECTIVE: To advance the state of the art in the capability to measure angle of incidence (AOI) through the use of external sensors and techniques which may include, but are not limited to: laser range measurement, photometry, etc.

DESCRIPTION: The lethality of certain weapon systems is in part a function of the AOI with respect to the target. AOI is the measured difference between weapon body axes and the target axes at impact. AOI may be a function of the attitude of the target at the moment of impact or, in the case of strike warfare, the topography of the ground or water target at the point of impact. It is estimated that AOI measurements could be obtained through the use of sensors on an orbiting platform as well as on the target itself. At present, no commercially available, off-the-shelf sensor suite exists to meet the following AOI measurement requirements:

AOI 3 DOF Angle of Incidence Error RMS <1 degree each axis

Steady State Position Vector Error to Store as Function of Time RMS <5 cm, <1 degree

Steady State Stores 3 DOF Attitude Error RMS as Function of Time <1 degree each Axis

PHASE I: Develop a sensor concept. This effort should include a study of existing technologies for consideration in the development of the concept.

PHASE II: Develop a prototype as a risk mitigation effort. Test and demonstrate this technology. The offeror shall develop viable demonstration cases by collaborating with the government or private sector entities.

PHASE III: Follow-on activities could be pursued by the offeror, namely to seek opportunities to integrate the demonstrated sensor technology into commercial test articles. Commercial benefits include improved competitive opportunities for providers of aerospace platform components and sub-systems.

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1. "Targeting At the Speed of Light", Richard L. Hughey, Lt Col, USAFR, Blue Horizons Paper, Center for Strategy and Technology, Air War College, 23 February 2007.

2. "Precision Guidance with Impact Angle Requirements", Jason J. Ford, DSTO Aeronautical and Maritime Laboratory, Oct 2001.

KEYWORDS: Angle of Incidence, Impact Angle, Precision Guided Munitions

AF131-180 TITLE: Directed Energy Wind Tunnel Test Methodology

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop a methodology for directed energy (DE) system testing in transonic wind tunnels that decouples mechanical vibration effects (jitter) from aero-optic aberrations due to density gradients in the shear layer above the DE turret.

DESCRIPTION: The development a test and evaluation methodology is needed that maximizes the information return from ground testing before committing to airborne directed energy (DE) systems flight tests. To date, the results of wind tunnel tests at matched flight conditions are of questionable value because of the difficulty in separating the wind tunnel dynamics from the aero-optic measurements of interest. Future ground tests of DE systems will be conducted only if it is possible to characterize the relative displacement and vibration of the laser source, the target, and wavefront sensors in the wind tunnel. During the planning phase for wind tunnel tests, the finite number of options for locating the source, target, and sensors are evaluated. If the dynamic environment of each location is known, a motion damping system could be used to mitigate the jitter present in the wind tunnel. The predicted residual jitter could then be used to estimate the feasibility of each laser shot within the limitations of the optical hardware. Therefore, an effective DE test methodology should include a wind tunnel dynamic environment measurement system capable of measuring the baseline wind tunnel motion over the range of flight conditions and the test peculiar environment of each DE installation. The output of the dynamic measurement system will be the input to existing optical system design software for determining the wind tunnel impact on the waveform. This would allow the actual waveform that has been diffracted and attenuated by the aero-optic features of the turret to be corrected for the wind tunnel contribution. The data protocol for existing DE optical design software and wind tunnel configurations will be made available. The Phase I should produce a measurement system architecture for vibration measurements and process definition for implementing the measurements to an DE optical design software program. Basic system vibrational measurements should be demonstrated in a laboratory environment. The ultimate goal is development of a system prototype that includes the dynamic environment measurement system with output vibration data compatible with existing optical design software. The final system prototype should be demonstrated in a simulated wind tunnel environment.

PHASE I: Develop a system design concept with detailed hardware and measurement requirements for quantifying wind tunnel structure vibrations.

PHASE II: Develop and demonstrate a prototype system in a relevant environment incorporating the measurements for removal of facility vibration effects from DE aero-optic test data.

PHASE III: The military and commercial wind tunnels have needs for highly accurate optical measurement systems with the ability to account for and understand the impacts of tunnel vibrations.

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1. Duffner, Robert W., Airborne Laser: Bullets of Light, Publication New York: Plenum Trade, August 21, 1997.

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3. Crosswy F. L., and A. G. Havener, “Aero-Optics Measurement System for AEDC Aero-Optics Test Facility, Technical Report AEDC-TR-90-20, 1991.

4. Hugo, R. J., E. J. Jumper, G. Havener, and C. Stepanek, “Time-Resolved Wave Front Measurements through a Compressible Free Shear Layer,” AIAA Journal Vol. 35, No. 4, pp. 671-677, April 1997.

KEYWORDS: Directed energy, vibration measurement, aero-optics, motion damping, optical design

AF131-181 TITLE: Computational Modeling of Coupled Acoustic and Combustion Phenomena Inherent to Gas Turbine Engines

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Development and validation of a computational model to simulate combustion processes coupled with acoustic phenomena to quantitatively predict acoustic waves, i.e. screech and rumble, inherent to gas turbine engines.

DESCRIPTION: There is a need for a validated computational model to simulate the combustion processes coupled with acoustic phenomena focus for military engine augmentors, i.e. afterburners, where coupled combustion and acoustic phenomena generate instabilities. Liquid fuel-injection combustion processes can stimulate strong acoustic waves inside hot sections of turbine engines. The origin of the acoustic waves can be traced, in some instances, to interactions of heat release combustion processes and geometric features of hot-section components. High-enthalpy heat release conditions inside the augmentor can stimulate strong longitudinal and circumferential standing acoustic waves, bounded in the axial upstream direction by the turbine exhaust case and downstream by the nozzle throat location. The amplitude of the waves can rapidly increase causing severe structural damage to the augmentor liner, which can limit the operability of the augmentor. These instabilities are known as “rumble” at low frequencies (< 100 Hz) and "screech" at higher frequencies (100 to 500 Hz). Currently, many engine manufacturers utilize computer codes based on empirical correlations to qualitatively predict these effects. The qualitative correlations have limited use in augmentor design, and usually fail to predict rumble and screech when the operating conditions extend beyond the bounds of the empirical correlation parameters. Existing measurements from applicable combustion unit/rig experiments and/or augmentor development tests should be researched, identified and utilized to generate a more cogent understanding of the basic processes that contribute to instabilities in engine augmentors. The approach should incorporate a detailed sensitivity study of various turbine engine geometry configuration and performance parameters to be utilized in the model development such as pressure losses, flame holding, length of the combustion zone, geometry, wall heating and etc. Deliverables should include the source code. Reliance on licensed software should be identified, but avoided if possible.

PHASE I: Perform a comprehensive evaluation and documentation of the current state-of-the-art technology, identify existing measurements applicable to this effort, and provide a rigorous description of the approach and methodology to be employed in developing and validating a high-fidelity numerical model.

PHASE II: Development and validation of the high-fidelity, physics-based computational model optimized for high performance computational environments.

PHASE III: Acoustic and combustion instability analysis is vital to military and commercial turbine engines to augment engine development and testing.

REFERENCES:
1. Ebrahimi, Houshang. B. “Overview of Gas Turbine Augmenter Design, Operation, and Combustion Oscillation,” AIAA 2006-4916, Joint Propulsion Conference, July 12, 2006.

2. Trinh, H.P., and Chen, C.P., “Modeling of Turbulence Effects on Liquid Jet Atomization and Breakup,” AIAA 2005-0154, 43rd AIAA Aerospace Sciences Meeting and Exhibit, 10-13 January, 2004, Reno, Nevada.

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KEYWORDS: augmentor, screech, rumble, gas turbine engine, combustion, computational model, acoustic, instability

AF131-182 TITLE: Non-Fluid Refrigeration Technology for Cooling Infrared Focal Planes and Other

System Components below 50 K in Cryo-Vacuum Test Chambers

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Provide a means of cooling infrared focal planes and other system components to their operating temperatures without significant consumption of cryogens.

DESCRIPTION: Fluid cryogen delivery systems used in ground testing of space-borne and air-borne imaging systems (such as infrared focal plane arrays using in monitoring projection radiometry) are problematic due to the cost and handling of liquid helium. These systems require significant infrastructure and large amounts of power to cool and store the cryogens. Additionally these systems are wasteful in that large amounts of cryogens are lost to boil-off and other inefficiencies in the system. Furthermore, these systems require Helium to reach the lowest temperatures. Helium is an environmentally limited resource and once lost, cannot be recovered. A reliable technique that does not use cryogenic fluids is needed (such as using magnetic or optical cooling) that can be used to achieve stable device temperatures in the 8 to 60 K temperature range. Such a cooling system must present minimal (<5 milli-g) vibration to the device being cooled. The device should provide a significant power savings over current systems to gain the maximum efficiency and environmental benefit.

PHASE I: Demonstrate a prototype non-fluid based closed-circuit refrigerator for use in continuously cooling a cryogenic focal plane array to 30 K with. Temperature control must be within +/- 0.1 K.

PHASE II: Based on Phase I results, build and demonstrate non-fluid based closed-circuit refrigerator for use in continuously cooling a cryogenic focal plane array to 8 K with. Temperature control must be within +/- 0.1 K.

PHASE III: Military: Low-vibration cooling of IR focal plane arrays for space- and air-borne sensors and IR test equipment. Commercial: Cooling for scanning electron microscopes, superconductors, cryo-vacuum chambers, medical instrumentation and freeze-drying of pharmaceuticals.

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1. Lowry, H. S., Nicholson, R. A., Simpson, W. R., Mead, K. D., Crider, D. H., and Breeden, M. F., “Test and Evaluation of Sensor Platforms in the AEDC Space Sensor Test Chambers,” AIAA-2005-7634.

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4. Callier, Maria, “Optical Refrigeration Expected to Enhance Airborne and Spaceborne Apps”, http://www.wpafb.af.mil/news/story.asp?id=123187569.

5. Yocum, K. Michael, et.al., “Improvement in Ge Detector Cooling”, 2008 Monitoring Research Review: Ground-Based Nuclear Explosion Monitoring Technologies, https://na22.nnsa.doe.gov/mrr/2010/PAPERS/06-09.PDF.

KEYWORDS: cryogens, active cooling systems, cryogenic flow control, space simulation testing, cryo-vacuum chambers

AF131-185 TITLE: Compact Multi-spectral Scene Projector Technology

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop new optical designs and projection techniques to provide low background flickerless generation of dynamic imagery over the wavelength band of about 0.4 to 5.0 microns.

DESCRIPTION: Present day scene projectors use an individually heated array of individually addressable resistors (i.e., a million tiny blackbodies) to generate a flicker-free dynamic infrared image. Such devices have limited utility from the standpoints of operability, dynamic range, uniformity, and spectral content. They will not provide realistic imagery at near infrared and visible wavelengths. What is needed is a new approach to scene projection to allow not only generation of traditional 3-12 micron images, but also operate below 3 microns down to 0.4 microns.

The design must consider the following desired characteristics:
1. Compact small footprint - can be bolted on to air frames
2. Off-axis readout or other stray light reduction system
3. Flicker-free greyscale operation
4. Capable of multi-spectral operation (simultaneous visible/SWIR/MWIR)
5. 48 micron or smaller pixel pitch
6. Capable of framing rates of 120 Hz or higher
7. Dead pixels, if any, must be few and cold
8. Low electrical power operation (compact and coolable to -35 C or lower)

PHASE I: The Phase I objectives will involve research and exploration of a variety of technical approaches to satisfy the desired characteristics listed in the description and choosing an optimum design approach to meet these goals as completely as possible. Furthermore, an estimate of expected performance should be developed for the technological approach chosen in this phase.

PHASE II: The Phase II objectives are:

1. Research the maturity, cost and performance issues associated with various technology options and recommend a proposed design solution.

2. Complete the prototype design for a scene projector.

3. Build a working prototype of the scene projector.

4. To image at least a partial array to verify performance expectations developed in Phase I.

PHASE III: A multi-spectral scene projector has commercial use primarily in the visible spectrum as presentation and movie projectors. For the military market, it will be an invaluable test tool for all forms of infrared sensors when display of uniform flicker-free dynamic imagery is needed.

REFERENCES:
1. D.B. Beasley et al (May 2005). Technologies for synthetic environments: Hardware-in-the-loop testing X. Proc SPIE, Vol. 5785, pp. 68-79.

2. J.C. Brazas and M.W. Kowarz (January 2004). High-resolution laser-projection display system using a grating electromechanical system (GEMS). Proc SPIE, Vol. 5348, pp. 65-75.

3. R. Ginn et al (May 16, 2006). Visible/UV image projector for sensor testing. Proc SPIE, Vol. 6208, 620800.

4. P. Halevei and F. Ramos-Mendieta (August 2000). Tunable photonic crystals with semiconducting constituents. PHYS REV LETT, Vol. 85, pp. 1875-1878.

5. Kang et al (April 2001). Electro-optic behavior of liquid-crystal-filled silica opal photonic crystals: Effect of liquid-crystal alignment. PHYS REV LETT, Vol. 86, pp. 4052-4055.

KEYWORDS: multi-spectral, low background, SWIR, flicker-free, image projection

AF131-188 TITLE: <u>Gas Turbine Engine Particle Emission Characterization</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a capability for fast measurements of gas turbine engine particle mass and number emission indices.

DESCRIPTION: The goal is to develop a fast, accurate capability for measurements of particle number density, size distribution and mass-based emission factors (indices) as an alternate to EPA Method 5 currently used by DoD for reporting turbine particulate matter (PM) emission rates. The DoD-JSF Environmental office, EPA, FAA and NASA have expressed this need to the SAE E31 Committee. Air bases, many in non-attainment areas, remain non-exempt from local air quality PM Regulations as upheld in courts, March 2002 [1]. Method 5 does not provide PM size (critical for health effect issues) and is costly, requiring long engine run times. Aircraft-generated PM is composed of nonvolatile particles (soot) and volatile particles, including volatile condensed onto nonvolatile. PM techniques used in research for determining particle size, number, and mass require fundamental research before EPA and FAA will accept the viability of these PM techniques and associated sampling methodologies for regulatory compliance. Current acceptable measurement practices do not provide real-time data [2]. Differential mobility analyzers and CNCs are used to measure number densities and size distributions [3]. Assumptions for particle shape factors and mass density, used to convert these measurements to mass-based emission indices, add a large uncertainty to the mass based emission indices thus determined. Fundamental research is required to experimentally determine these shape factors and particle mass densities as a function of combustion aerosol size for aircraft engine emissions to thus define and possibly eliminate these uncertainties. Measurements in the laboratory and on a variety of engines are required to establish correlations for shape factor and mass density to engine type and engine operating conditions. Ultimately, a fast technique (~1 Hz per 10-1000 nm dia. scan) is required for measuring accurate number densities, size distributions and mass based emission factors as a function of engine type and operating condition for engines in a variety of test environments to provide a sound, accurate basis for DOD to report PM emission rates to the regulatory authorities.

PHASE I: Demonstrate the feasibility of resolving measurement system particle density and particle shape factor effects.

PHASE II: Develop a prototype measurement system for fast particle emission indices in gas turbine engine exhausts.

PHASE III: Military applications include environmental reporting of military aircraft, potential quantitative replacement of smoke number, and fast diagnostic for plume observables.

REFERENCES:
1. Office of Air Quality Planning & Standards, “Draft Staff Paper for Particulate Matter Fact Sheet,” Environmental Protection Agency, Washington DC, August 2003. http://www.epa.gov/ttn/oarpg/t1/fact_sheets/pmfdsp_fs.pdf.

2. SAE E31 Committee, “Nonvolatile Exhaust Particle Measurement Techniques,” SAE E31 AIR5892 Committee Aerospace Information Report.

3. SAE E31 Committee, “Nonvolatile Exhaust Particle Measurement Techniques,” SAE E31 AIR6037 Committee Aerospace Information Report.

4. Schmid, Otmar, Hagen, Donald, Whitefield, Philip, Trueblood, Max, Rutter, Andrew, and Lilenfeld, H., “Methodology for Particle Characterization in the Exhaust Flows of Gas Turbine Engines,” Aerosol Science & Technology Volume 38, Number 11 / November 2004, pages 1108 – 1122.

KEYWORDS: Gas Turbine, Particle Number, Size, Mass, Volatile, Nonvolatile

AF131-189 TITLE: <u>Wind Tunnel High Temperature Heater Element</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To develop and demonstrate a scalable electrically-powered heater element to generate 2800 degree Fahrenheit continuous airflow in the test section of a supersonic/hypersonic wind tunnel.

DESCRIPTION: To replicate the conditions experienced by vehicles flying at high Mach number, sustained airflow temperatures of 2800 degrees Fahrenheit are required. Some tunnels, such as the NASA Langley Research Center 8-ft High Temperature Tunnel (HTT) facility and the NASA Glenn/Plum Brook Hypersonic Tunnel Facility (HTF) have not only met this temperature requirement, but have exceeded it; however, the solutions chosen have provided insufficiently short run times, have introduced undesirable test media from combustion products introduced into the flow in the case of vitiation heated facilities, such as HTT, or from foreign object debris (FOD) into the flow in the case of facilities like the HTF, and/or have required difficult or excessive levels of maintenance.

Heater elements for high Mach wind tunnels, in general, have been in use for decades now, ranging from combustion air systems with run times on the order of seconds to combinations of gas heat exchangers and electric boost heat which may run continuously. However, the availability of ground test facilities which can provide large clean air mass air flows (~150 lbm/sec) and high temperatures (~2800 deg F) continuously that closely simulates flight conditions has proven elusive thus far.

A favorable heater element, or group of elements, will be capable of being installed in a 1-3 foot diameter duct, withstand static pressures of 2000 psi, provide continuous operation for periods lasting up to four hours, and have a minimum total expected life of 200 hours at maximum operating condition. Electrical and mechanical properties will not be noticeably degraded due to oxidation and other phenomena during the 200-hour operating life.

PHASE I: A single heater element, or group of elements, will be constructed and demonstrated. Current, voltage, thermal shock, thermal expansion, and mass/structural characteristics will be examined. A candidate integrated heater final design concept to be developed as a Phase II, and performance validated in a government-furnished wind tunnel facility, will be delivered.

PHASE II: The Phase II effort will fully develop and fabricate the final design concept from Phase I for demonstration in a government-furnished wind-tunnel environment.

PHASE III: Development of large-scale wind tunnels for military high Mach number aircraft, propulsion systems, and weapons.

REFERENCES:
1. W900KK-08-R-0017 Amendment 4 Broad Agency Announcement - Advanced Instrumentation Systems Technology Science & Technology (AIST S&T).

2. Thomas, Scott R.; Lee, Jinho; Stephens, John W.; Hostler, Robert W.; and Von Kamp, William D.: The Mothball, Sustainment, and Proposed Reactivation of the Hypersonic Tunnel Facility (HTF) at NASA Glenn Research Center Plum Brook Station. AIAA-2010-4533.

3. Reardon, J. and Warmbrod, J.: Design of a Radiant Heater for AEDC Tunnel C. AEDC-TR-89-1, Feb. 1989.

4. Micol, J.R.: Langley Aerothermodynamics Facilities Complex: Enhancements and Testing Capabilities. AIAA 98-0147.

5. Steinle, FW; Tatum, KC; and Groff, RD: Feasibility of Mach 6 Clean Air Continuous-Flow Heater Using SiC Elements." AIAA 2009-7360.

KEYWORDS: Mach number, hypersonic, ramjet, scramjet, wind tunnel

AF131-190 TITLE: Dimensional Restoration of Aircraft Components Damaged by Corrosion

TECHNOLOGY AREAS: Materials/Processes, Electronics

OBJECTIVE: To resolve issues with aircraft components damaged by corrosion in hidden and/or hard to access locations by providing a capability for on-site dimensional restoration of damage awhile providing improved corrosion protection.

DESCRIPTION: Current methods for restoration of corrosion affected aircraft components in the Air Logistics Complex (ALC) are in need of process improvement and equipment enhancement. In order to align with high velocity maintenance (HVM) procedures in use in the ALCs, the improved methods for restoration must be capable of relatively quick removal of corrosion products and dimensional restoration of substrates and be applicable to complex geometries and internal bores. Preferred methods will also require no surface finishing after dimensional restoration and will provide precise control over thickness of applied repair material.

Also required are environmentally friendly methods of restoration that do not require use of hazardous materials and generation and disposal of hazardous wastes, such as chromate containing primers and coatings. Eliminating hazardous waste will significantly reduce cost of corrosion repair.

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Portability of the method/equipment will facilitate on-site repairs.

There has been a considerable body of research leading to innovations in equipment and repair processes which can lead to solutions for the issues with the process of dimensional restoration on complex aircraft component surfaces. Use of commercial of the shelf (COTS) equipment and methods, especially those approved for use in related applications, can provide significant efficiency and cost savings to the Air Force, without delays attending extensive R & D and testing.

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PHASE I: Perform research to identify and characterize components, areas requiring dimensional restoration, material types, damage areas and requirements for restoration (shape, size, thickness, and design to correct or limit corrosion). Provide a concept demonstration of the technical approach and methodology to determine feasibility of prescribed applications.

PHASE II: Based on the technologies and methods identified in Phase One and presented during the concept demonstration, develop a streamlined solution for dimensional restoration to be used across Air Force Material Command (AFMC) depots. Demonstrate the solution(s) in a real-world environment and obtain MIL-SPEC approval for use of the process in the ALC depots and possible transition into commercialization applications.

PHASE III: Based on success of the Phase II prototype applications and approved repair restoration process updated in the MIL Specification, provide proposals to sponsoring organizations for implementation into depot. Proposals should include the supporting portable production ready equipment required for restoration, training required on all phases of the operation, and equipment installation for each application approved during Phase II and updated MIL Specifications. Similar applications in general aviation community that meets the same requirements of the updated MIL Specifications would be available for commercialization of the processes.

REFERENCES:

1. Aircraft Cleaning and Corrosion Control - http://www.faa.gov/library/manuals/aircraft/amt_handbook/media/faa-8083-30_ch06.pdf

2. Air Force Corrosion Prevention and Control Program - https://www.corrdefense.org/Academia%20Government%20and%20Industry/SERVICE%20OVERVIEWS%20-%20BULLOCK%20-%20%20AFCPCO%20Tri-Service%20Conf%20paper.pdf

3. Air Force Corrosion Prevention and Control Office - http://www.asetsdefense.org/documents/Workshops/SURF-FIN-TempeAZ-02-08/Briefings/Doak-AF_Corr_Prev_&_Ctrl.pdf
http://afcpo.com/

KEYWORDS: corrosion, repair, prevention, dimensional restoration, substrate application

AF131-191 TITLE: Image Quality Indicator(s) and Software for Computed Radiography (CR)

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Define a standardized method using resident software tools, and/or adapt existing third-party software, to measure an image quality metric (e.g. signal-to-noise ratio (SNR); contrast-to-noise ratio (CNR), etc.) on any CR system.

DESCRIPTION: A penetrameter, or IQI, is used to determine radiography quality and qualify (whether a shot can be read and allowed to be interpreted) each x-ray shot processed with regular film in radiographic testing. Computed radiography systems are now used in lieu of traditional wet films to process images in some radiographic testing inspection requirements in the ALCs and field installations. It is widely expected that due to rapid advances in CR technology and with the worldwide effort to eliminate hazardous waste by-product of radiographic testing (i.e., silver, chemicals, etc.), use of CR will increase AF wide.

An Image Quality Indicator (penetrameter) is often required when performing radiographic inspection in the ALCs. IQIs are required to ensure that the quality of the radiograph could be trusted to show flaws or defects of interest could be identified. However, visual evaluation of an IQI is subjective, and one of the potential advantages of digital radiography is the ability to implement advanced software tools which allow discrete measurements. One of the findings in the recently concluded CR projects conducted by the AF showed that penetrameters used in film radiography are not always effective when used with CR image processing and cannot always ensure that flaws or defects of interest on CR images are acceptable. An image quality approach implementing measurement of image metrics needs to be developed to ensure that when performing radiographic inspection, defects and flaws of interest could be seen in the CR images at all times.

Using image metrics with CR has been evaluated by several programs. The recently concluded AF CR project demonstrated that using resident software tools to measure SNR or CNR resulted in inconsistent measurements, not only from manufacturer to manufacturer, but even within the same region on an image. Third-party software has been developed and is available that reportedly provides consistent SNR data, but integration into AF systems has not been demonstrated. ASTM is implementing CNR guidance for digital detector arrays, but this approach was found ineffective for CR in a Metals Affordability Initiative study. Likewise, IQI development efforts are underway at some OEMs, but have not been demonstrated on CR systems (only on digital detector arrays).

It is important to design, develop and create CR IQIs and accompanying software measurement tools to ensure that radiographic images provide the necessary quality required for critical applications. Once validated, verified, and proper probability of detection is conducted, this image quality approach could be used, not just by the AF and the DoD, but by users of CR throughout the world.

Using CR, evaluate typical aluminum airframe cracks in specimens or structures up to 2 inches thick. Crack specimens are available as GFE. Access will be provided to up to three types of USAF CR systems (two CR manufacturers) at one or more USAF facilities to collect data. Two different manufacturer's CR workstations will be provided as GFE for data analysis. Identify types and sizes of cracks in CR images that couldn't be identified when traditional wet film penetrameter indicates that the CR images are acceptable (i.e., crack visible only at proper technique, but IQI visible at improper technique as well).

PHASE I: Research, design and provide a concept demonstration that can be used to detect defects and flaws that could be missed when using traditional wet film penetrameters. Draft a Phase II plan to develop, validate and implement an image quality solution applicable to computed radiography system.commercially available in the US.

PHASE II: Finalize CR IQI design, build, validate and verify IQI performance on all types of CR systems qualified for crack detection in the AF inventory (4 systems) using software and crack specimens. Perform POD by demonstrating the flaw detection rate of the new CR IQI and software compared to traditional wet film penetrameter using various specimens with known cracks, and using sample of AF NDI technicians reading images and identifying crack indications.

PHASE III: Concern for lack of CR image quality assessment that could be used for radiographic inspection in the AF is not limited to the USAF or to the DoD. A reliable CR images IQI could be used throughout the nondestructive testing industry worldwide.

REFERENCES:
1. "USAF Computed Radiography System Performance Qualification Test Procedure for Airframe Crack Detection Applications", 24 Oct 2011, AFRL/RXSA (Appendix A of report No. AFRL/RXS 12-002 "Computed Radiography Systems for USAF Airframe Crack Detection Applications and Development of System Performance Requirements and Product Description", 2 Feb 2012).

2. "Guidelines for the Use of Digital Detector Arrays and Computed Radiology for Aerospace Casting Inspections", Metals Affordability Initiative (MAI) program, 18 Aug 2011.

KEYWORDS: Nondestructive testing inspection, Image Quality Indicator, Penetrameter, Radiographic Inspection, Computerized Radiography, Imaging Plates, Probability of Detection (POD)

AF131-192 TITLE: Corrosion Identification, Removal and Cleaning of Galvanic Couples in Difficult to Access Areas

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Provide improved technologies that provide earlier detection and ease of repair for the inspection, detection, and removal of corrosion from aluminum (Al) alloy galvanic couples in difficult to access areas of components and/or end items.

DESCRIPTION: Almost all metals used in aerospace are subject to corrosion of various types. One form of corrosion that is of great concern is dissimilar metals corrosion. When two dissimilar metals are in contact and connected by an electrolyte, accelerated corrosion of one of the metals will occur. The more easily oxidized surface becomes the anode and corrodes. The less active member of the couple becomes the cathode of the galvanic cell. The degree of attack depends on the relative activity of the two surfaces; the greater the difference in activity, the more severe the attack. When metals from two different groups are in contact with each other, special protection is required to identify galvanic coupling to detect corrosion, especially hidden corrosion in difficult to access areas.

The existing methods of corrosion inspection, detection, removal and repair in the Air Logistics Complex (ALCs) are in need of process improvement and equipment enhancement. Early detection of corrosion is difficult, in some components and regions of the end items (aircraft, missiles, ground support equipment, etc.). Often, aircraft and their components must be partially disassembled in order to accurately detect and access areas in need of repair. Once corrosion has been detected, specialized equipment and materials, including abrasive blast media and hazardous solvents, are required in conjunction with removal. These methods are costly, time consuming, labor-intensive, and result in undesirable environmental conditions including the release of Volatile Organic Compounds (VOCs), particulate matter, and dusting. Moreover, these methods are not precise and cannot be effectively used to remove corrosion damage from hard to reach areas and areas adjacent to critical features. The need for disassembly of the end item contributes to the inefficiency of repairs and decreases the availability of weapons systems to warfighters.

Ideally, corrosion would be repaired in-place, with minimal removal of parts to access areas inside the structure. An in-depth assessment of the corrosion repair processes would identify areas that can be improved in efficiency, ease of use, and reduced environmental impact. There have been numerous improvements to equipment and techniques that will contribute to a solution for the issues encountered during the corrosion removal and repair process. Cross utilization existing commercial of the shelf (COTS) manufacturing readiness level (MRL) 8/9 equipment and methods, especially those approved for use in related commercial and general aviation applications, could provide significant efficiency and cost savings across the defense industrial base (DIB). But cross utilization requires research, process engineering, and further development, prior to substitution and implementation into DoD.

PHASE I: Develop an innovative technology, methods and approach that will provide earlier detection and improved ease of repair procedures or capability. Provide a concept demonstration and report that includes technology developed, methodologies, and procedures for corrosion detection, removal, cleaning and repair without damaging the underlying substrate or adjacent features.

PHASE II: Based on the outcome of Phase 1 concept demonstration, develop the technology for a prototype system that address the collective needs of the described applications. Test the prototype system in a real-world environment and obtain MIL-SPEC approval for use of the process within Air Force Material Command (AFMC).

PHASE III: The equipment and methods developed in response to this solicitation can be used in corrosion repair and prevention efforts throughout the DoD, commercial and general aviation industries. Laser technologies are prime candidates to be cross utilized from cleaning to coating removal.

REFERENCES:
1. Aerospace Corrosion Protection by John Routledge, http://EzineArticles.com/5791942.

KEYWORDS: corrosion repair, corrosion prevention, aluminum alloy, galvanic coupling

AF131-193 TITLE: Composite Calibration Standards Kit for Calibration of Multiple Equipment in the AF Inventory Used for Composite Nondestructive Inspection (NDI)

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design, develop, and create composite calibration standards kit that can be used to calibrate multiple NDI equipment used in the AF ALCs and field installations that reduce inspection frequency and reduce procurement cost.

DESCRIPTION: Due to rapid growth in use of composite materials not just in the aerospace but in other types of industries as well, there is proliferation of commercially available NDI equipment used in various methods such as ultrasonic, shearography, thermography, and radiography for composite testing. The AF has several in the inventory for nondestructive inspection of composite materials of aircraft structures and parts.

During life cycle maintenance, these parts undergo NDI processes designed to identify potentially critical flaws that could cause catastrophic failure of the aircraft. The three Air Logistics Complexes and supporting field installations apply many kinds of NDI equipment utilizing various technologies and vendor models. To perform composite nondestructive testing inspections, initial calibration of the equipment is required using a series of equipment composite calibration reference standards with known flaws. For example when inspecting using ultrasonic and eddy current equipment on metallic structures or parts, calibration reference standards are readily available and used interchangeably among instruments by different manufacturers. There are no composite calibration reference standards that could be used interchangeably. Each weapon system in the AF inventory that uses composite, has calibration standard specifically designed only for specific instrument but can't be used to calibrate other types of composite instrument.

To ensure that all nondestructive testing equipment used for composite inspection in the AF is calibrated correctly, general purpose composite calibration standards, need to be designed and developed that could be used interchangeably to calibrate all composite NDI equipment in the AF inventory.

Research type and size of defects and flaws inspected with composite NDI equipment in the AF. Identify characteristic part geometries of composite equipment calibration standards and their application interchangeability for use on composite NDI equipment in the AF inventory.

PHASE I: Identify range of composite materials that are used on AF aircraft. Demonstrate methodology where the Phase I design calibration standards that could fulfill equipment usage interchangeability applications when using other types of composite NDI equipment.

PHASE II: Build, determine applicability, validate and verify performance of composite equipment calibration standards designed in Phase 1 against all composite NDI equipment in the AF inventory. Perform POD by demonstrating flaw detectability on composite calibration standards using ultrasonic, shearography, thermography, and radiography equipment utilizing sample of AF NDI technicians.

PHASE III: Many industries utilize composite NDI methods and could be interested in a set of composite standards that could be used interchangeably with all of the commercially available NDI equipment for composite testing.

REFERENCES:
1. T.O. 33B-1-1

2. MIL-HDBK-1823

KEYWORDS: Composite Nondestructive testing inspection, Calibration Standards, Probability of Detection (POD)

AF131-196 TITLE: Landing Gear Strut Operational Readiness Monitoring

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 5.4.c.(8) of the solicitation.

OBJECTIVE: Develop an innovative approach for monitoring and assessing the operational readiness of landing gear struts. Specific considerations for fluid level confirmation, pressure verification and temperature measurement.

DESCRIPTION: Landing gear shock struts utilize an oleo-pneumatic (oil/gas) design which provides the primary load path from ground reactionary forces to the airframe structure. Ground maneuvers from stopping, turning and towing transmit loads through the shock strut to the airframe. A critical characteristic role of the shock strut is to cushion impact forces due to landing by converting some of the aircraft's kinetic energy into heat, which is dissipated through the conduction/convection heat transfer from the fluid through the outer cylinder and piston. This critical function ensures that the airframe structure does not experience high impact loads which could negatively impact the structural integrity of the airframe, increasing mishap risk and/or maintenance burden and costs. In order for the shock strut to operate and function properly it must have the correct gas to fluid ratio. Once a strut is serviced, it is a closed fluid and gas system with minimal external indications of proper and/or improper servicing. Physical inspections are the primary means of monitoring and assessing the operational readiness of shock strut systems. These inspections, many required on a daily basis, are time-consuming and often result in improper servicing in order to satisfy mission schedules and demands. Accurate assessment of landing gear operational readiness is not a trivial requirement and must be addressed appropriately if mishaps and airframe damage are to be avoided. Given recent technological improvements, including robust sensors, wireless communication devices, and miniaturized data acquisition systems; a multi-function system can be developed which has the ability to measure and transmit landing gear operational parameters to the maintainer in real-time and have the capability for data storage. Critical primary characteristics to be measured and transmitted are hydraulic fluid level and gas pressure with additional information such as temperature being secondary. The acquisition system and data transmittal need be unobtrusive with minimal impact to the strut configuration. Power for system operation shall be self contained. The system needs to be easily accessible for removal and replacement if necessary. The ability to check and verify the condition of landing gear shock struts without physical inspection will significantly reduce the maintenance burden and support readiness objectives.

PHASE I: Determine the technical feasibility of developing a multi-function system that can be used to capture and assess the operational readiness (fluid level, pressure, and temperature) of shock strut systems. Conduct preliminary feasibility evaluations and down-select those approaches considered to be most appropriate for further consideration.

PHASE II: Fully develop, demonstrate, and validate a multi-function landing gear shock strut monitoring system, using the equipment/approaches identified in Phase I, on a representative landing gear system. Ensure that the proposed system is highly reliable and that it satisfies the performance objectives defined in Phase I. Develop and provide an overall cost benefit analysis for the multi-function system developed as well as a conceptual implementation strategy plan for a fleet-wide retrofit program.

PHASE III: Commercial aircraft landing gear are functionally equivalent to military aircraft landing gear. The desire for reduced maintenance on commercial aircraft will mirror the USAF requirement. Validated shock strut monitoring equipment will benefit both commercial and USAF market.

REFERENCES:

1. Aircraft Landing Gear Design: Principles and Practices; Norman S. Currey; 1988.

2. Flying Safety Magazine, The Mysterious x-Dimension; Chad Hogan P.E. and Craig Pessetto P.E.; August 2002.

3. Metallic Materials Properties Development and Standardization (MMPDS); Battelle Memorial Institute.

4. Drawing 1, Main Landing Gear Outer Cylinder for KC-135, uploaded in SITIS 12/12/12.

5. Drawing 2, Main Landing Gear Outer Cylinder for KC-135, uploaded in SITIS 12/12/12.


KEYWORDS: Strut, OLEO-pneumatic, kinetic energy, airframe, structure, sensors, wireless, operational readiness

AF131-197 TITLE: <u>Advanced OSHA Compliant Blast Cleaning Rooms (No Blast/HM Residue Migration Outside Blast Cleaning Room)</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a BCR & BC to eliminate potential exposure to HM in & around the BCR, & BC; identify HM migration pathways out of typical BCR & BC & develop methods to eliminate those migration pathways, or control the potential exposure below the OSHA PEL.

DESCRIPTION: The United States Air Force (AF) operates many hundreds of blast cleaning rooms (BCR) and Blast Cabinets (BC) for WS Sustainment. BCR comply with MIL-PRF-32037. The BCR and BC utilize Plastic Media for the removal of organic coatings (ref MIL-P-85891A). Other BCR and BC operations utilize other grit-blasting materials including wheat starch or walnut shells to aggressive aluminum oxide. The blasting operations remove paint top coats, which contain numerous HM, and corrosion prevention primers containing hexavalent chromium (Cr+6). Blasting operations can also liberate Cadmium (Cd) from nut plates and Landing Gear components. The OSHA Permissible Exposure Limits (PEL) to Cr+6 and Cd is so small that any migration of these metals out of the BCR, and BC, constitutes a potential exposure hazard to the workforce, and an OSHA violation. Abrasive blasting is also used for removing rust, ash, paint, burned-on carbon, scale, and oxidation. The dust and HM in the dust, generated from these, and other blasting processes, create potential health hazards for the BCR and BC operators, and workers in adjacent work areas, and personnel walking through the BCR and BC work areas and other locations throughout the buildings operating a BCR or BC. HM from BCR and BC dust has been found in adjacent break areas, and wash facilities and is a source of potential exposures to personnel walking through these areas. Each of these locations constitutes potential OSHA violations, wherever the BCR and BC dust and HM migrate.

The AF has relied on engineering controls, personal protective equipment, and BCR and BC operator training to eliminate, or keep potential exposure to BCR and BC Dust and HM below the OSHA PEL. Standard controls are inadequate to achieve the OSHA PELs for BCR Operators and work area PELs. The AF Air Logistics Complexes were recently inspected by OSHA. OSHA issued several findings regarding BCR and BC exposures and migration of BCR dust and HM outside the BCR.

In order to provide our workforce the safest work environment, and eliminate the migration of HM out of the blast processes, the AF seeks to develop the best available controls, including a sealed BCR and BC, to eliminate fugitive Dust and HM migration, including migration of HM by transport on Blast Operators leaving the BCR. This novel BCR and BC will eliminate, or minimize, BCR and BC Operators and the general workforce in a BCR/BC operating facility from potential exposures to airborne blasting dust, and HM removed from substrate structures in the blasting process. Any new BCR or BC operation which has an effect on the WS Structure or part being processed in the BCR or BC must be fully tested for the effect. The testing results must be briefed to and approved by the System Program Office (SPO) for the affected WS.

PHASE I: Phase I will evaluate BCR & BC in nonclassified work areas and describe HM migration from BCR & BC causing work area and & adjacent areas' break rooms, wash rooms, change facilities, admin areas' contamination from BCR & BC and propose a Phase II prototype BCR & BC. Phase I will develop methods eliminating BCR & BC operator identified HM migrations and methods to seal BCR & BC eliminating migration of HM BCR & BC.

PHASE II: Phase II will develop prototype BCR & BC and demonstrate Phase I proposed BCR & BC comply with MIL-PRF-32037 and applicable parts of OSHA Occupational Health & Environmental Control Std. 1910.94, Ventilation. The Phase II Prototypes will demonstrate ability to keep dust, toxic metals, & aerosols, below their OSHA PELs & validate that dusts andHM do not migrate out of the BCR & BC. Phase II will also identify the actions which could impact WS parts & coordinate testing with AF WS engineers and production engineers.

PHASE III: BCRs & BCs will be built; a Mil-Std and an American National Standards Institute (ANSI) standard will be written and submitted for Advanced Zero Leakage OSHA Compliant BCR & BC. The BCR & BC can be used by DOD, replacing OSHA noncompliant BCR & BC. BCR & BC is applicable in industries using BCR & BC.

REFERENCES:

1. OSHA Occupational Health and Environmental Control Standard 1910.94, Ventilation.

2. Performance Specification, Blast Cleaning Room MIL-PRF-32037.

3. Military Specification, Plastic Media, For Removal of Organic Coatings MIL-P-85891A.


KEYWORDS: blast cleaning rooms, Blast Cabinets, sealed blast rooms, sealed blast cabinets, blast room ventilation

AF131-198 TITLE: Find substitute for Methylene Chloride in depaint operations at Hill AFB

TECHNOLOGY AREAS: Air Platform, Materials/Processes, Electronics

OBJECTIVE: Identify an effective substitute for MeCl that does not contain haz air pollutants & can not interfere with the metal removal process at industrial waste treatment plant. Substitute must meet mil-spec requirements for landing gear maintenance.

DESCRIPTION: Methylene chloride is a regulated OSHA toxic and hazardous substances as well as a hazardous air pollutant (HAP) under the Clean Air Act. Landing gear maintenance facility at Hill AFB services aircraft landing gear, brake and wheels. Due to complex geometry of the variety of landing gears, wheels and brakes paint on the components is difficult and very labor intensive to remove. Current practice of dipping parts in methylene chloride solution to loosen paint adhesion followed by plastic media blast, although effective and efficient, uses over 16, 000 gallons per year of methylene chloride based stripper. Replacing methylene chloride with more environmentally friendly alternatives will enable the base operation to eliminate the use of methylene chloride based solvent, provide a safer environment for the workers, and significantly reduce the emission of HAPs.

The suitable substitute must remove the paint/grease as or more effectively then the methylene chloride process. The substitute must also be shown to be safe on landing gear parts made of materials such as aluminum alloys (for example 2014 and 7000 series) and high strength steels (for example 4340 and 300M). Among the properties to be tested for safety are corrosion, hydrogen embrittlement and fatigue. If removal can be achieved chemically without having to blast with media afterwards, we have achieved our goal. Production time is also factored into this acceptance, due to the volume of parts being handled; we must find a replacement that will work within current time frames to ensure we do not impact production.

PHASE I: Potential substitute(s) will be identified specific to Hill's production needs. This will include evaluation of substitute process requirements in comparison with current process, meeting Technical Order and Mil-Specs for landing gear paint removal activities, laboratory scale testing of efficiencies, bench testing of compatibility with substrates and compatibility with IWTP’s treatment process.

PHASE II: The substitutes identified in Phase I shall be tested to show their safety with landing gear materials. During phase II, substitute(s) identified in Phase I will be studied in a prototype production line at the maintenance facility using condemned parts. Parameters evaluated in Phase I will be expanded and operational data will be collected to demonstrate the production and economic feasibility of the substitutes (high strength steel, aluminum alloys).

PHASE III: Phase III will see the full scale implementation of substitute process at Hill AFB landing gear maintenance facility & recommended other potential applications on base. Commercial & industrial activities that strip paint can benefit from using the developed substitute, demonstrating dual use.

REFERENCES:

1. AFRL/CTC's report on Non-acid Based, Alternative Paint Strippers to Methylene Chloride, April, 2012.

2. ASTM 519.

3. TO 4S-1-182.

4. TO 4W-1-61.

5. TO 1-1-8.

6. Environmental and Energy Quality Technologies, MeCl Replacement Technology, Final Report (CDRL A015), March 30, 2012, 29 pages. (Uploaded in SITIS 12/14/12.)

KEYWORDS: methylene chloride, depaint, degrease, paint stripper, landing gear

AF131-199 TITLE: Blast Booth Noise Reduction - An OSHA Compliance Issue

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To reduce employee exposure to hazardous noise during Blast Cleaning Room (BCR) and Blast Cabinets (BC) abrasive media blasting operations to or below OSHA 8-Hour Time Weighted Average without increasing ergonomic stress on the operator.

DESCRIPTION: Currently Air Logistics Complexes and many other DOD maintenance, repair, and overhaul organizations use compressed air abrasive media blasting to remove materials from surfaces and prepare surfaces to receive coatings. These operations are conducted in blast cleaning rooms, and blast cabinets. During these operations operators are exposed to compressed air blast nozzle volumes of 99dBA-110dBA to as high as 132dBA. Which resulted in the 2011 OSHA Citation 1, Item 1: Employees were subjected to sound levels exceeding those listed in Table F-16 of Subpart G of 29CFR 1910.95 and feasible administrative or engineering controls were not utilized to reduce sound levels.

Blast cleaning rooms (BCR's) and blast cabinets (BC's) range in size from a large breadbox to enclosures large enough to fit entire aircraft or ground equipment. BC's are somewhat small and are operated through gloved ports in the side of the cabinet. BCR's can be the size of a hangar and are operated by an operator(s) inside the BCR. Both BC and BCR operators can be subjected to compressed air blast nozzle noise exceeding 132dBA. BCR's blast operations are performed using one or more dual-action, 1.25 in. diameter X .25 in. wall, high pressure (100psi) compressed air hoses that release compressed air only or compressed air with abrasive media at the flip of a switch. These hoses provide the air used to; blast (blow-down) the metal surfaces with abrasive media and to blow-off the dust and debris with compressed air.

In addition to the noise hazard, employees performing abrasive media blasting operations experience ergonomic stress resulting from the size, weight and stiffness of the compressed air hose. Employees working in blast areas using thicker walled hoses experience higher stress and fatigue and report a higher number of stress related injuries. Therefore, systems engineered noise abatement/exterior operator solutions must not increase operator ergonomic/musculoskeletal stressors above current levels.

Currently, employee exposure to blast booth noise is being monitored by industrial hygienist and all operators are enrolled in the Hearing Conservation Program. Bio-Environmental controls include utilizing 20+dB NRR ear muffs over 20+db NRR ear plugs and time-limited work periods in some blast areas.

The attenuation provided by PPE (ear plugs and muffs) is generally insufficient to provide the Air Force standard dose of 85 dBA equivalent continuous level for 8 hours. Many processes include daily time limits as low as 30 minutes per worker total exposure per day to keep noise dose under 100%.

This topic solicits an R&D engineered solution(s) that will provide manned hearing safe and/or automated BC and BCR environments that meet or exceed current production rates, does not induce any additional ergonomic stress on the operator(s) and meets or exceeds OSHA's 8-Hour TWA for noise.

PHASE I: Establish feasibility of and development path to BOTH, engineered 90dBA manned, AND unmanned pneumatic abrasive blast coating removal operations in currnet BCR and BC work areas using media such as steel peen, walnut shell, CO2, starch, garnet and Quick Strip.

PHASE II: Phase II – Design, develop and test a prototype of the system/strategies developed in Phase I in a relevant operational environment AND Provide an engineering development plan sufficient to demonstrate the ability to provide a viable pilot manufacturing line.

PHASE III: DEMONSTRATE the technology in an OPERATIONAL environment and Provide fully coordinated transition plan which addresses all technical readiness & manufacturing readiness necessary to transition from engineering development to commercial products for government and non-government customers.

REFERENCES:

1. OSHA Standard 29 CFR 1910.95, Occupational Noise Exposure.

2. Performance Specification, Blast Cleaning Room MIL-PRF-32037.

3. Military Specification, Plastic Media, For Removal of Organic Coatings MIL-P-85891A.

KEYWORDS: pneumatic abrasive blast, compressed air abrasive blast, abrasive blast, sand blast, blast booth, blast cabinet, blast booth noise, blast booth noise hazard, industrial blast booth noise, noise hazard

AF131-202 TITLE: Surface Treatments for Stainless Steel Actuators

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop surface treatments to improve the wear and damage tolerance of steel actuators for aircraft subsystems.

DESCRIPTION: Stainless steel ballscrew components, such as those found in landing gear and flap actuators, experience wear due to friction and foreign object damage (FOD). The Air Force incurs a high maintenance burden associated with frequent inspections and applications of lubricants in the field in an effort to keep actuators functioning at a high availability rate.

Coatings such as Electrolytic Hard Chrome (EHC) have been utilized on actuator components for numerous years. There are many benefits to EHC such as providing an excellent wear surface, a good corrosion barrier and ability for surface restoration to dimensional tolerances during the repair and overhaul process. However, EHC has been systematically phased out due to its environmental and health hazard risks, and replacement coatings have not offered comparable hardness or low friction performance. New surface treatments are needed that improve the surface hardness and lubricity of the steel actuator surface, in order to minimize FOD damage and provide a permanent dry lubricant.

Current ballscrew, jackscrew and sliding rail actuator components for flaps and landing gear are made with 4XXX series steels. These steels must be protected with corrosion protection coating systems to improve actuator life. Current specified coatings include magnesium phosphate, zinc phosphate and hard chrome coatings. Phosphate coatings are porous, have high friction, and must be repeatedly sealed with lubricants to improve both friction and corrosion performance. These coating systems are prone to hydrogen embrittlement and use environmentally hazardous materials/processes.

Current components are qualified to 16,000 hours but fall well short due to environmental (corrosion, wear, contamination) issues. There are a myriad of issues on the different components. Landing gear ballscrew actuators may wear out prior to a full PDM cycle due to wear/galling - rocks and debris from unimproved runways damage the surface of the actuator, causing accelerated wear. Flap actuators/rails must be completely disassembled every 270 days to reapply corrosion-inhibiting brush coatings, causing a huge amount of maintenance labor. Without these coatings, actuators would likely fail within 1 year or less as the 4XXX steel is not very corrosion resistant on its own. In addition, brush coatings on the sliding rails must be reapplied after every aircraft wash cycle (100-150 days).

Current surface hardness requirement for the steel substrate and coatings is 55-59 HRC (~700-900HV). As stated previously, this is a problem as contaminants/FOD that would damage the coatings are often harder (1100-1200HV). Advanced carbon-based coatings (DLC, vanadium carbide, chromium carbide) provide hardness in the range of 1500-3000+ HV (75-90 HRC). These coatings also have the benefit of being extremely dense with coefficients of friction below 0.1, which means no secondary lubricant/corrosion inhibitor topcoat is required. Current phosphate (lubricated) and chrome coatings have COF of 0.12-0.16.

The goal of this project is to develop surface treatment processes that both increase the surface hardness as well as the lubricity of the steel actuator substrate while maintaining high fatigue resistance. The process must be both cost-effective and suitable for large-scale manufacturing applications.

PHASE I: Investigate the application of surface engineering techniques for steel actuator components in order to achieve lower friction and improved surface hardness while maintaining high fatigue and corrosion performance. Phase I will consist of coating and testing on representative surface geometries.

PHASE II: Demonstrate and validate Phase I effort on coupons simulating landing gear components. Conduct coupon-level validation testing for corrosion, surface hardness, fatigue, microstructure, coating bond strength and coating integrity. Demonstrate surface treatments on full-scale actuator components and perform system-level validation test. No government test facility should be needed.

PHASE III: Military application: To be used on DOD military aircraft landing gear and flap actuators. Commercial application: There is a possible use on civilian cargo and passenger aircraft landing gear and flap actuator components. Industrial uses also include sealing surfaces.

REFERENCES:
1. Menthe, E., Rie, K-T, Schultze, J. W., & Simson, S. (1994). Structure and properties of plasma-nitrided stainless steel. Surface and Coatings Technology (Switzerland), 74(1-3), 412-416.

2. Pfaffenberger, E. E., & Tarantini, P. (1993, June). High temperature corrosion resistant bearing steel development. Paper presented at the AIAA/SAE/ASME/ASEE 29th Joint Propulsion Conference, Monterey, CA.

3. Menthe, E., Bulak, A., Olfe, J., Zimmerman, A., & Rie, K.-T. (2000). Improvement of the mechanical properties of austenitic stainless steel after plasma nitriding, Surface and Coatings Technology, 133/134(2000), 259-263.

4. Larisch, B., Brusky, U., & Spies, H.-J. (1999). Plasma nitriding of stainless steels at low temperatures. Surface and Coatings Technology (Switzerland), 116-119, 205-211.

KEYWORDS: Electrolytic Hard Chrome, Foreign Object Damage,Stainless Steel Ballscrew

AF131-203 TITLE: <u>High-Efficient Liquid Desiccant and Chloride Removal for Corrosion Mitigation and Control</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a high-efficient liquid desiccant system with the added capability to remove chloride along with moisture from the atmosphere. The reduction of chloride and humidity will greatly reduce the corrosion potential.

DESCRIPTION: Of the $4.5B spent on aircraft corrosion maintenance by the Air Force annually, $1.1B is spent on corrective maintenance for corrosion defects and $3.4B is spent on labor for corrosion related maintenance. Humidity and chloride are key components in forming and accelerating corrosion in all environments. It has been proven that when humidity is maintained below 50% that the corrosion can be prevented. This will ensure that the atmosphere does not allow for the moisture to condense and dissolve the chloride to provide the electrons for the galvanic potential.

Corrosion occurs from the chemical reaction on materials when the environmental conditions contain humidity and alkalinity characteristics. Chiefly, aircraft aluminum will break down in humid and salty (sodium chloride) environments from galvanic corrosion. Dehumidification has been shown to reduce corrosion by reducing the humidity to lower levels in the air. But, this technology leaves the chloride in the air which can coat the material. When the metal is moved to a humid location, it potentially has a concentrated amount of chloride covering. By developing a technology that combines dehumidification with chloride removal, we can greatly reduce the galvanic corrosion potential by in effect reducing corrosion related maintenance cost.

The goal of this topic is to develop, test and evaluate a dehumidification system which will provide a corrosive-free atmosphere in an aircraft environment. Chloride and environmental sensors will record and validate the reduction of these corrosive elements. This will provide a means to mitigate and control many forms of corrosion, such as uniform, pitting, galvanic, intergranular, exfoliation, filiform, crevice, and concentration cell corrosion. This technology will result in reduced maintenance manhours, reduced labor costs, and reduced cost of corrosion Air Force wide. Additionally, this technology will be adaptable to a variety of military systems within the Air Force and other services.

PHASE I: Conceptualize and design a liquid-desiccant system to maintain humidity to below 50% and remove chloride from the atmosphere. Develop chloride and environmental sensors to adequately measure favorable conditions. Develop a case example to demonstrate the technology's feasibility. Quantify the potential benefits of the technology through appropriate metrics.

PHASE II: Develop a prototype of the liquid-desiccant system that will be applied to actual aircraft, support equipment and war readiness materiel, buildings and storage units.

PHASE III: Finalize the liquid-desiccant technology implementation with DoD end customer for wide-scale fielding and technical order incorporation. Identify components where such material technologies may be applicable. Develop a technology transition plan and pursue a commercialization agenda.

REFERENCES:
1. Salt Free Evaporative Air Conditioning http://www.google.com/patents/US5341655.

2. How corrosion is impacted by salt http://library.kcc.hawaii.edu/external/chemistry/everyday_corrosion.html.

KEYWORDS: High-Efficient Liquid Desiccant, Corrosion Mitigation, Galvanic Potential

AF131-204 TITLE: Aircraft Maintenance Management to Unanticipated Failure Events

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: This topic seeks the development, testing and demonstration of a novel approach to planning and scheduling of aircraft maintenance practices at the depot level when unanticipated fault/failures are discovered upon arrival of the aircraft.

DESCRIPTION: The Air Force's Air Logistics Centers are charged with the responsibility to maintain the Air Force's aircraft fleet to its maximum readiness level at all times by ascertaining that maintenance, repair and overhaul tasks are carried out optimally in terms of the time each aircraft spends at the depot, the cost of repair, the quality of service, etc., i.e., these critical assets will be available and perform reliably when needed.

The ALCs perform scheduled aircraft maintenance following a well-defined planning and scheduling protocol that involves initial inspection, disassembly, repair, assembly and testing upon the arrival of the aircraft at the depot. Historical records, maintenance logs, observations, etc., are typically used to define a sequence of repair tasks for critical aircraft components/systems and to allocate maintenance shops for actions dictated by the schedule.

This "routine" maintenance schedule is pursued in the absence of anomalous or unanticipated events detected during the initial inspection stages. In the event, though, of a severe unanticipated occurrence (cracks on critical airframe components, leaks, corrosion, missing components, etc.) the current schedule, as a static tool, does not allow for dynamic re-planning to accommodate efficiently and effectively the new status of the vehicle so that significant repair delays are avoided or minimized.

Maintenance efficiency is an important initiative for ALCs and a major driver for this topic. The proposed re-planning tool must deliver relevant information about the status of the aircraft and integrate this information into the maintenance/repair schedule. It must integrate seamlessly with legacy (Concerto, PDMSS, EMIS data mart, RCAN) and future systems (as available) from static data to real-time, as necessary. It must produce schedules that are constantly improved by genetic algorithms which are informed by existing scheduling systems. Streamlining the amount of time an aircraft spends in the depot is the motivation for initiatives like High Velocity Maintenance (HVM) and others enabling improvements in aircraft operational availability. Technologies that improve the information available to the maintainer will enhance the HVM process and provide measurable gains.

A dynamic planning and re-planning technology is required that is capable of evaluating the impact of such unanticipated events on the overall maintenance schedule, re-planning on-the-fly to optimize depot resources available and expedite the time the aircraft spends on the ground. Dynamic re-planning can be viewed as a fault-tree modeling and constrained optimization problem. It must be integrated seamlessly into existing software while it accommodates learning and adaptation algorithms allowing for continuous improvement of the depot maintenance/repair practices.

The contractor must identify metrics to show quantifiable improvements with re-planning in terms of the mean time the asset spends on the ground, the efficiency and quality of service, etc. The contractor must develop and test in simulation initially an optimized re-planning strategy in the presence of unanticipated events to prioritize repair activities and demonstrate quantifiable benefits to the ALCs. Access to available data and information regarding current planning/scheduling practices will be provided to the contractor by Warner Robins ALC.

PHASE I: Phase I work will focus on the conceptualization, initial development and demonstration via simulation of the dynamic re-planning tool and associated models given the discovery of an unanticipated fault/failure event upon initial inspection of the aircraft.

PHASE II: This phase of the program will build upon the findings of Phase I and develop, test and evaluate an optimized re-planning tool; the tool must be integrated into available schedules and exhibit attributes of learning and adaptation; it must consider other related ALC activities aimed to achieve improved maintenance efficiency, such as High Velocity Maintenance, Work Scope Optimization, etc. Transitioning of the final re-planning package to AF operations must be considered.

PHASE III: This phase will result in a fieldable package that can be installed in ALCs and other AF facilities to augment current planning/scheduling software and improve the efficiency of maintenance and related operations.

REFERENCES:
1. Camci, F., Valentine, G.S., “Optimum Maintenance Scheduling for Complex Systems using Mixed Integers Linear Programming,” 60th Meeting of the Society of MFPT, April 2006.

2. Vachtsevanos, G., Lewis, F., Roemer, M., Hess, A., and Wu, B., “Intelligent Fault Diagnosis and Prognosis for Engineering Systems”, John Wiley and Sons, September, 2006.

KEYWORDS: Dynamic Re-planning, High Velocity Maintenance, Unmanned Aerial Vehicles

AF131-206 TITLE: Networked Sensor Systems for Aircraft Maintenance

TECHNOLOGY AREAS: Materials/Processes, Sensors

OBJECTIVE: Create novel networked sensor systems for aircraft maintenance system to enhance existing aircraft maintenance capability.

DESCRIPTION: Aircraft electrical and mechanical subsystem failures and the time to perform subsystem maintenance reduce aircraft availability and mission readiness. Intermediate and flight-line maintenance personnel do not always have the benefit of the current detailed health status and maintenance history of the aircraft at the time aircraft maintenance is performed. Typically, aircraft maintenance is dependent on a post-flight written and/or verbal debrief provided by the pilot(s). All too often, the maintenance personnel do not benefit from all of the existing aircraft health status and maintenance information. Failure mechanisms include leaks in the hydraulic fluid or fuel lines due to corrosion and wear of the lines from the fluids, gaseous contaminants or abrasive media. For many repair scenarios today, a cost and readiness driver is the absorption of fluids into composite structure. Hydraulic fluid is certainly the most widespread contaminant today, and its removal is a costly and time consuming process.

The leaks of interest fall in two categories. First are aircraft chemicals that cause corrosion. Most common among these are hydraulic fluid, aircraft fuel, lubricants, deicing fluids, and cleaners. Second are environmental contaminants like humidity, oxidizers (Ozone, NOx, SOx, etc.), radiation (heat, ultraviolet), and biological organisms. These fluid line and surface leaks could be located in hard to reach places around the body of the aircraft. An integrated sensor network system that can access these hard to reach locations and provide near-real time feedback on the integrity of the fluid and fuel handling systems and would minimize the inspection burden while providing meaningful information to the aircraft maintenance crew.

Such a leak detection system can be used in combination with new computing and information systems technology to design and develop a just-in-time aircraft maintenance system to automatically collect, store, manage, and intelligently exploit the health status and maintenance records of the aircraft in a timely manner for the benefit of the aircraft maintenance personnel. The end result is aimed at reducing the time to accomplish the necessary maintenance on the aircraft, thereby improving mission readiness. This integrated approach of vehicle health management systems will enable analysis of the current and historical data to determine and report aircraft health status, failures, and recommended maintenance actions. The system can take advantage of new computing and software technologies to minimize impact to the aircraft and maintenance process in terms of space, power, and weight. The system will ideally integrate seamlessly with existing maintenance processes. Several wireless technologies are being considered or in use to transmit/upload maintenance information to the ground crew prior to the aircraft landing to minimize down time and enhance mission preparedness.

PHASE I: Propose a preliminary design for a prototype version of either the aircraft chemical leak or the environmental contaminant detection system for confined or hard to reach places. This effort shall address the system architecture, the application of new technology, design trade-offs, implementation issues, integration with existing aircraft, and how it will achieve the objective of this topic.

PHASE II: Develop the detailed design and a prototype of the offeror’s proposed aircraft leak detection system. The offeror shall demonstrate the prototype system on an aircraft platform using viable test plans that clearly validate that the system will improve the performance of the aircraft maintenance.

PHASE III: Develop production version(s) of the aircraft leak detection system for integration into one or more US military aircraft and associated maintenance processes. Commercial Application: Explore applications of the JIT aircraft leak detection system for commercial aircraft.

REFERENCES:
1. Hess, A., "The Joint Strike Aircraft Prognostics and Health Management," 4th Annual Systems Engineering Conference, 22-25 October 2001. Available at http://www.dtic.mil/ndia/2001systems.

2. http://www.spectroline.com/aviation/aviation_dyes.html Aero-Brite™ Universal Fluorescent Leak Detection Dye.

3. Christodoulou, L. and Larsen, J.M., "Using Materials Prognosis to Maximize the Utilization Potential of Complex Mechanical Systems," Journal of Materials, Vol. 56, No. 3, pp. 15-19, March 2004.

4. NTSB Report detailing fluid contamination; www.ntsb.gov/Recs/letters/2006/A06_27_28.pdf.

5. Abaris Training; http://www.netcomposites.com/education.asp?sequence=69.

KEYWORDS: Aircraft maintenance, fault isolation, mission readiness, maintenance history