

**AIR FORCE**  
**19.2 Small Business Innovation Research (SBIR)**  
**Phase I 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. **Firms must ensure their proposal meets all requirements of the Broad Agency Announcement currently posted on the DoD website at the time the announcement closes.**

The AF Program Manager is Mr. David Shahady. The AF SBIR/STTR Program Office can be contacted at [afsbirsttr-info@us.af.mil](mailto:afsbirsttr-info@us.af.mil). For general inquiries or problems with the electronic submission, contact the DoD SBIR/STTR Help Desk via email at [sbirhelpdesk@u.group](mailto:sbirhelpdesk@u.group) (9:00 a.m. to 6:00 p.m. ET, Monday through Friday). For technical questions about the topics during the pre-announcement period (02 May 2019 through 31 May 2019), contact the Topic Authors listed for each topic on the Web site. For information on obtaining answers to your technical questions during the formal announcement period (31 May 2019 through 01 July 2019), go to <https://sbir.defensebusiness.org>. Your complete proposal **must** be submitted via the submissions site at <https://sbir.defensebusiness.org/> on or before the **8:00 pm ET, 01 July 2019 deadline.**

General information related to the AF Small Business Program can be found at the AF Small Business website, <http://www.airforcesmallbiz.af.mil/>. 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](http://www.sba.gov), and the Procurement Technical Assistance Centers, <http://www.aptacus.us.org>. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

(Continued on next page.)

CHART 1: Consolidated SBIR Topic Information

Applicable Topics	Phase I					Phase II			
	Technical Volume (Vol 1)	Additional Info (Vol 5)	Award Amount	*Technical Duration	*Final Reporting Period	Technical Volume (Vol 1)	Additional Info (Vol 5)	Technical & Reporting	Initial Award Amount
Special Topics AF192-001 only	Not to exceed 5 pages	Attach a pitch deck not to exceed 15 slides	Not to exceed \$50,000	2 months	1 month	Not to exceed 15 pages	Attach a pitch deck not to exceed 15 slides. Phone/video interview.	Typically 15-27 months	Not to exceed \$1,500,000
Pitch Day Topics AF192-005 thru AF192-006	Not to exceed 5 pages	Attach a pitch deck not to exceed 15 slides	Not to exceed \$75,000	2 months	1 month	Not to exceed 15 pages	Attach a pitch deck not to exceed 15 slides. Phone/video interview.	Typically 15 months	Not to exceed \$750,000
All Other Topics	Not to exceed 20 pages	See requirements below	Not to exceed \$150,000	6 months	3 months	Not to exceed 50 pages	See requirements below	Typically 27 months	Not to exceed \$750,000

\*The technical duration and final reporting duration must be added together for the total duration of the project.

**AF Special Topic Information**

The Air Force SBIR/STTR Program office is continuing to pilot new processes via “AF Special Topics” (AF192-001) in order to accelerate technologies to the warfighter. The AF Special Topics are different in several ways from the standard AF SBIR/STTR proposal, award and execution. Special Topics have shortened technical durations, reduced reporting requirements, and varying award amounts compared to normal SBIR Topics. There are additional unique features associated with each of the Special Topics that are listed in the sections below. Consolidated information on all SBIR topics can be found in Chart 1.

**Special Topics AF192-001**

AF192-001 is sponsored by AFWERX (link in the BAA announcement) a catalyst for agile Air Force engagement across industry, academia, and non-traditional contributors to create transformative opportunities and foster an Air Force culture of innovation. The NAICS Code for this acquisition is 541715, (Research and Technology in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology) and the small business size standard is 500 employees.

### **Pitch Day Special Topics (AF192-005 thru AF192-006)**

The Air Force SBIR/STTR office is continuing its Pitch Day Special Topics as a SBIR Special Topic process for topics AF192-005 thru AF192-006. Each Pitch Day Topic revolves around tying in one of the Air Force's Program Executive Officer (PEO) offices in order to further reduce obstacles and rapidly develop and field technology relevant to that specific PEO's needs. Offerors should take note of the unique technical duration, award amount and proposal submission requirements (Volume 1 and Volume 5) for these Special Topics (see Chart 1). A unique feature for the Pitch Day Topics comes in the 2-part evaluation process explained below:

1. The first evaluation will utilize the Evaluation Criteria provided in Section 6.0 of the DoD BAA. Once the evaluations are complete, all offerors will be notified as to whether they will be invited to the pitch their proposal at the Air Force Pitch Day event.
2. Offerors that were selected will receive an invitation to make a live pitch to the Air Force team during separate events to be held in July 2019. AF192-005 will be at 1 Beacon St in Boston and AF192-006 will take place at the Northeastern University Kostas center in Burlington, Ma. During the Air Force Pitch Day events, the selectees will be required to physically present an updated and reduced version slide deck that was included in Volume 5 of their original 19.2 proposal. Companies must be present at the event and complete their pitch to AF evaluators in order to receive an award. This presentation will be evaluated by a panel against the Section 6.0 of the DoD BAA.

Once the evaluations are complete, all offerors will be immediately notified as to whether they were selected or not selected for a Phase I award. Selectees should be ready to sign and receive a contract at the Air Force Pitch events. In order to expedite funds, selectees should also be able to accept an initial payment under the contract through a Government Purchase Card (GPC) as part of the conditions of award. Further information on the Air Force Pitch Day will be made available as the event date gets closer at <https://www.afsbirsttr.af.mil/>

For all Special Topics, the Phase I proposals shall include a technical volume (uploaded in Volume 1) that shall not exceed 5 pages and a pitch/slide deck not to exceed 15 slides (uploaded in Volume 5). The technical volume and slide deck will be reviewed holistically and there is no set format requirements for the two documents. It is recommended (but not required) that more detailed information is included in the technical volume and higher level information is included in the pitch deck. The cost volume (Volume 3) for the Special Topics will cover the total effort broken down into the specified technical and reporting periods (See Chart 1 for specific times). AF Special Topics shall follow the Phase I Work Plan Outline as noted in the "Phase I Work Plan Outline" section below except that there is only one required Progress report and no requirement for a Technical review due to the short technical durations. Final reporting for Phase I awardees will take the form of a presentation (with a SF298) in accordance with the Contract.

It is critical that proposers for the Special Topics are registered in the System for Award Management, <https://www.sam.gov/>, you will not be eligible for an award if not registered. Additionally, verify that you are registered to receive contracts (not just grants) and that your address matches between your proposal and SAM.

The AF Special Topics call for Phase II proposals shall occur shortly after Phase I award. The AF Special Topics will have specific Phase II instructions. Unless otherwise stated in the Special Topics paragraphs above, all other requirements as noted below apply to the AF Special Topics. If there are any questions with the AF Special Topics, please contact [afsbirsttr-info@us.af.mil](mailto:afsbirsttr-info@us.af.mil).

## **PHASE I PROPOSAL SUBMISSION**

Read the DoD program announcement at <https://www.acq.osd.mil/osbp/sbir/solicitations/index.shtml> 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 a standard 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 (for standard Phase I's). **The contract period of performance for awards under AF Special Topics is different. See Chart 1 above section for details.**

The Phase I standard topic awardees must accomplish the majority of their primary research during the first six months of the contract with the additional three months of effort to be used for generating final reports. 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 8.0 of the DoD announcement. The last three months of the nine-month Phase I contract (for standard topics) will provide project continuity for all Phase II awardees so no modification to the Phase I contract should be necessary.

### **Limitations on Length of Proposal**

**The Phase I Technical Volume (for standard topics) has a 20-page-limit (excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), Company Commercialization Report.** The Technical Volume must be in no type smaller than 10-point on standard 8-1/2" x 11" paper with one (1) inch margins. 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 will not be considered for review or award. The documents required for upload into Volume 5 "Other" category do not count towards the 20-page limit. **The technical volume page limit for proposals against the AF Special Topics are different. See Chart 1 above for details.**

NOTE: The Fraud, Waste and Abuse Certificate of Training Completion (Volume 6) is required to be completed prior to proposal submission. More information concerning this requirement is provided below under "**PHASE I PROPOSAL SUBMISSION CHECKLIST**".

### **Phase I Proposal Format**

**Proposal Cover Sheet:** 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. 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. If your proposal does not appear after an hour, please contact the DoD SBIR/STTR Help Desk via email at [sbirhelpdesk@u.group](mailto:sbirhelpdesk@u.group) (9:00 am to 6:00 pm ET Monday through Friday).

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

### **Phase I Work Plan Outline**

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

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

Scope: List the major requirements and specifications of the effort.

Task Outline: Provide a brief outline of the work to be accomplished over the span of the Phase I effort.

Milestone Schedule

Deliverables

Kickoff meeting within 30 days of contract start

Progress reports (Only 1 for AF Special Topics)

Technical review within 6 months (N/A to AF Special Topics)

Final report with SF 298

### **Cost Volume**

Cost Volume information should be provided by completing the on-line Cost Volume and including the Cost Volume Itemized Listing 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. For the Special Topics, the cost volume will cover 2 months of technical effort (see Chart 1) and 1 month of reporting. For the standard topics, the cost volume will cover a 9 month effort to include 6 months of technical effort and 3 months of reporting. 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 will not count against the 20-page limit (or the 5 page/15 slide limit for AF Special Topics). The itemized listing may be placed in the "Explanatory Material" section of the on-line Cost Volume (if enough room), or may be submitted in Volume 5 under the "Other" dropdown option. (Note: Only one file can be uploaded to the DoD Submission Site). Ensure that this file includes your complete Technical Volume and the information below.

- 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 rationale.
- 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. For AF Special Topic AF192-001 greater travel expectations will be required as noted in the topic statements and corresponding SITIS Q&A.
- f. Cost Sharing: If proposing cost share arrangements, please note each standard topic Phase I contract total value may not exceed \$150,000 total, while Phase II contracts shall have an initial Not to Exceed value of \$750,000. Please note that cost share contracts do not allow fees. NOTE: Subcontract arrangements involving provision of Independent Research and Development (IR&D) support are prohibited in accordance with Under Secretary of Defense (USD) memorandum "Contractor Cost Share", dated 16 May 2001, as implemented by SAF/AQ memorandum, same title, dated 11 July 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. 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 <http://www.afsbirsttr.af.mil/Program/Overview/> should be included in your cost proposal. Full text for the clauses included in the P.O. may be found at <http://farsite.hill.af.mil>.

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. 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. The Government reserves the right to conduct discussions if the Contracting Officer later determines them to be necessary.

j. DD Form 2345: For proposals submitted under export-controlled topics (either International Traffic in Arms (ITAR) or Export Administration Regulations (EAR)), a copy of the certified DD Form 2345, Militarily Critical Technical Data Agreement, or evidence of application submission must be included. The form, instructions, and FAQs may be found at the United States/Canada Joint Certification Program website, <http://www.dla.mil/HQ/InformationOperations/Offers/Products/LogisticsApplications/JCP/DD2345Instructions.aspx>. Approval of the DD Form 2345 will be verified if proposal is chosen for award.

**NOTE: Restrictive notices notwithstanding, proposals may be handled for administrative purposes only, by support contractors; U.Group, Oasis Systems, Riverside Research, Peerless Technologies, BRTRC and/or Stealth Entry LLC. AF Special Topic 192-001 proposals will be reviewed but not evaluated by The Dcode Group, Inc. as part of a commercial viability readiness review. In addition, only Government employees and technical personnel from Federally Funded Research and Development Centers (FFRDCs) MITRE and Aerospace Corporations working under contract to provide technical support to AF Life Cycle Management Center and Space and Missiles Centers may evaluate proposals. All support contractors are bound by appropriate non-disclosure agreements. If you have concerns about any of these contractors, you should contact the AF SBIR/STTR Contracting Officer, Michele Tritt, [michele.tritt@us.af.mil](mailto:michele.tritt@us.af.mil).**

k. The Air Force does not participate in the Discretionary Technical and Business Assistance (TABAs) program. Contractors should not submit proposals that include Discretionary Technical and Business Assistance.

### **PHASE I PROPOSAL SUBMISSION CHECKLIST**

NOTE: If you are not registered in the System for Award Management, <https://www.sam.gov/>, you will not be eligible for an award. Additionally, verify that you are registered to receive contracts (not just grants) and that your address matches between your proposal and SAM.

1) The Air Force standard topic Phase I proposal shall be a nine-month effort, and the cost shall not exceed \$150,000. **These parameters for proposals against the AF Special Topics are different. See Chart 1 above for details.**

2) The Air Force will accept only those proposals submitted electronically via the DoD SBIR Web site (<https://sbir.defensebusiness.org/>).

3) You must submit your Company Commercialization Report electronically via the DoD SBIR Web site (<https://sbir.defensebusiness.org/>).

4) The Air Force Special Topic AF192-001 requests that a Funding Agreement Certification be completed and signed at time of proposal submission and included in Volume 5. This certification can be found at: <https://www.afsbirsttr.af.mil/Program/Phase-I-and-II/> under "Phase I and II Certification – Funding Agreement."

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, Fraud, Waste and Abuse Certificate of Training Completion and the Company Commercialization Report -- be submitted

electronically through the DoD SBIR Web site at <https://sbir.defensebusiness.org/>. Each of these documents is to be submitted through the Website.

Please note that the Fraud, Waste and Abuse Training must be completed prior to submission of your proposal. This is accomplished under Volume 6 of the DoD SBIR Web site (<https://sbir.defensebusiness.org/>). When the training has been completed and certified, the DoD Submission Website will indicate this in the proposal which will complete the Volume 6 requirement. The Fraud, Waste and Abuse Certificate of Training website can be found under Section 3.6 of the DoD 19.2 SBIR BAA Instructions. If the training has not been completed, you will receive an error message. Your proposal cannot be submitted until this training has been completed. Your complete proposal **must** be submitted via the submissions site on or before the **8:00 pm ET, 01 July 2019 deadline**. A hardcopy **will not** be accepted.

The AF recommends that you complete your submission early, as computer traffic gets heavy near the announcement 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. The AF is not responsible for ensuring notifications are received by firms changing mailing address/e-mail address/company points of contact after proposal submission without proper notification to the AF. Changes of this nature that occur after proposal submission or award (if selected) for Phase I and II shall be sent to the Air Force SBIR/STTR site address, [afsbirsttr-info@us.af.mil](mailto:afsbirsttr-info@us.af.mil).**

## **AIR FORCE PROPOSAL EVALUATIONS**

The AF will utilize the Phase I proposal evaluation criteria in section 6.0 of the DoD announcement in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), followed by the potential for commercialization as detailed in the Commercialization Plan.

The AF will utilize the Phase II proposal evaluation criteria in section 8.0 of the DoD announcement in descending order of importance with technical merit being most important, followed by the potential for commercialization as detailed in the Commercialization Plan, followed by the qualifications of the principal investigator (and team).

The proposer's record of commercializing its prior SBIR and STTR projects, as shown in its Company Commercialization Report, will be used as a portion of the Commercialization Plan evaluation. If the "Commercialization Achievement Index (CAI)", shown on the first page of the report, is at the 20th percentile or below, the proposer will receive **no more than half** of the evaluation points available under evaluation criterion (c) in Section 6 of the DoD 19.2 SBIR instructions. This information supersedes Section 5.4 e, Paragraph 4, of the DoD 19.2 SBIR instructions.

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

## **Proposal Status and Debriefings**

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. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced. **If changes occur to the company mail or email address(es) or**



**company points of contact after proposal submission, the information should be provided to the AF at [afsbirsttr-info@us.af.mil](mailto:afsbirsttr-info@us.af.mil).**

As is consistent with the DoD SBIR/STTR announcement, any debriefing requests must be submitted in writing, received within 30 days after receipt of notification of non-selection. Written requests for debrief must be submitted via [www.afsbirsttr.af.mil](http://www.afsbirsttr.af.mil) through the SBIR system. Requests for debrief should include the company name and the telephone number/e-mail address for a specific point of contact, as well as an alternate. Also include the topic number under which the proposal(s) was submitted, and the proposal number(s). 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. 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.

## **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, located here: <http://www.afsbirsttr.af.mil/Program/Phase-I-and-II/>. Phase II efforts are typically 27 months in duration (24 months technical performance, with 3 additional months for final reporting), and an initial value not to exceed \$750,000. **The length of the Phase II technical effort and reporting period for efforts that were Phase I awards under the AF Special Topics are different. See Chart 1 above for details.**

NOTE: Phase II awardees should either have or start working towards having 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 have questions regarding this matter, please discuss with your Phase I Contracting Officer.

**All proposals must be submitted electronically at <https://sbir.defensebusiness.org/> by the date indicated in the notification. The Technical Volume is **limited to 50 pages** (unless a different number is specified in the notification; **Phase II proposals on AF Special Topics will have different limitations. See Chart 1 above for details**). 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: For Phase II applications 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 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).

## AIR FORCE SBIR 19.2 Topic Index

AF192-001	Open Call for Innovative Defense-Related Dual-Purpose Technologies/Solutions with a Clear Air Force Stakeholder Need
<del>AF192-002</del>	<del>Agile Technology Insertion for Small Unmanned Aerial Systems [removed]</del>
<del>AF192-003</del>	<del>Artificial Intelligence and Decentralized Control for UAV Swarms [removed]</del>
<del>AF192-004</del>	<del>Open Call for Innovative Space Technology with a Clear Air Force Stakeholder Need [removed]</del>
AF192-005	Kessel Run Pitch Day
AF192-006	Unmanned Aerial Systems Pitch Day
AF192-007	Standardized, Compact, and Automated Shock Tube for Fuel Characterization and Modeling
AF192-008	Millimeter wave Instrumentation and Characterization
<del>AF192-009</del>	<del>Fusion of Multi-Modal Data Sources for Entity/Event Alignment [removed]</del>
<del>AF192-010</del>	<del>Airborne Low-Swap Optical Communications [removed]</del>
<del>AF192-011</del>	<del>THz Power Amplifiers [removed]</del>
<del>AF192-012</del>	<del>THz Airborne Antenna Technology [removed]</del>
<del>AF192-013</del>	<del>Reducing Cyber Vulnerability Risk without Test Cases [removed]</del>
AF192-014	RF Situational Awareness with Low-Cost Signal Samplers
AF192-015	Low SWAP-C Anti-Jam Techniques for MGUE Increment 2 Handheld Receiver
AF192-016	Heterogenous Power Exploitation in GPS Receivers
AF192-017	W-band Receive Phased Array for SATCOM Uplinks
AF192-018	Dual-Band, Multi-Platform High Power Amplifiers for SATCOM Uplinks
AF192-019	V-band Transmit Phased Array for SATCOM Downlinks
AF192-020	V-Band Crosslink Solid-State Power Amplifiers
AF192-021	High Spectral Resolution Longwave Infrared Hyperspectral Imaging System
AF192-022	Develop Small Pitch Geiger Mode Avalanche Photodiode Detector Arrays for Multifunction LiDAR Receivers
AF192-023	Conformal Beam Steering for High Resolution Ladar
AF192-024	Cognitive Fully Autonomous Sensor Technology (CFAST)
AF192-025	Fully Adaptive Radar Resource Allocation
AF192-026	Advanced Hyperspectral Exploitation Using 3D Spatial Information
AF192-027	Compact Broadband Thermal Imaging and LWIR HSI Payload for Small Unmanned Aircraft System (SUAS)
AF192-028	EO/IR-Specific State of the Art Machine Learning
AF192-029	High-Resolution Rapid Refresh (HRRR) Weather Nowcasts
AF192-030	Next Generation Miniature Charged Particle and Multi-Phenomenology Detectors
AF192-031	Non-destructive Imagery and Analysis Techniques for Identification of Deleterious Defects in Li-ion Batteries
AF192-032	Novel Sensor Solutions for Qualification of Additively Manufactured Launch and Space Vehicle Components
AF192-033	Next Generation Device Attachment Thermal Interface Material
AF192-034	Laboratory Benchtop Accelerator for Charged Particle Detector Calibration
AF192-035	Develop Prototype Hyperspectral Microwave Imager for Terrestrial Weather
AF192-036	Large Area Solar Simulator for Next Generation Solar Panels
AF192-037	Military GNSS Data Server
AF192-038	Development of Graphene Batteries for Use in Space Applications
AF192-039	Plug-and-Play Technology for Distributed Modular Propulsion Engine Controls Design
AF192-040	Development of a High Performance, Printed Conformal Li Battery
AF192-041	Erosion Resistant Coatings for Large-Diameter Gas Turbine Engine Compressor Integrally-Bladed Rotors (IBRs) and Lift-Fan Blades
AF192-042	Advancement of High Energy Rechargeable Lithium Batteries
AF192-043	High Performance Solid Rocket Propellant Replacement
AF192-044	Propulsion for Agile, Resilient Spacecraft
AF192-045	Advanced Integrated Engine Control Test Bed for Development of Intelligent Systems and Smart Instrumentation

AF192-046	Passive Coatings for Aircraft Drag Reduction
AF192-047	MQ-9 Battery Technology Improvements
AF192-048	Hypersonic Vehicle Electrical Power Generation through Efficient Thermionic Conversion Devices
AF192-049	Data Science Based Approaches for Modeling Optimal Controls and PHM for Power and Thermal System Components.
AF192-050	New Methods, and Technologies Required for Heat Rejection from Next Generation Aircraft
AF192-051	Optically Gated, Wide Bandgap Semiconductors for Aircraft Electrical Actuator Motor Drives
AF192-052	Additively Manufactured Reactor For high performance, non-toxic monopropellants
AF192-053	Development of High Energy Software Control System
AF192-054	Small High Reliability Electrical/Signal Connectors for Gas Turbine Engine Applications
AF192-055	New Concepts for High Temperature Turbine Engine Oil Pumps
AF192-056	Low Cost Mission Enabling Cold Start for Small Engines
AF192-057	Dynamic, Risk-Based, Situational Awareness and Response
AF192-058	Delivery System and Compatible Chemicals for Rapid Collapse of Hi-EX Foam
AF192-059	Unmanned Aerial System (UAS) Aircraft Rescue and Firefighting (ARFF)
AF192-060	A small multi-spectral Imagery Pod to Provide High Resolution Rangeland Management Data
AF192-061	Energy Storage/Real-Time Peak Shaving
AF192-062	Determination of Significant Failure Size for Finite Element Analysis (FEA)
AF192-063	Ergonomic Dead Man Switch on Blast Nozzles
AF192-064	MIL-PRF-85285 Capable “Controlled-Spray” Head for Automated Stenciling of Aircraft Markings
AF192-065	High Precision, Non-Line-of-Sight Point Cloud Generation
AF192-066	All-electronic Switch Exceeding 10 THz

## AIR FORCE SBIR 19.2 Topic Descriptions

AF192-001            TITLE: Open Call for Innovative Defense-Related Dual-Purpose Technologies/Solutions with a Clear Air Force Stakeholder Need

TECHNOLOGY AREA(S): Materials/Processes

OBJECTIVE: This is an AF Special Topic in partnership with AFWERX, please see the above AF Special Topic instructions for further details. A Phase I award will be completed over 3 months with a maximum award of \$50K and a Phase II may be awarded for a maximum period of 27 months and \$1,500,000. The objective of this topic is to explore Innovative Defense-Related Dual-Purpose Technologies that may not be covered by any other specific SBIR topic and thus to explore options for solutions that may fall outside the Air Force's current fields of focus but that may be useful to the US Air Force. An additional objective of this topic is to grow the industrial base of the US Air Force. This topic will reach companies that can complete a feasibility study and prototype validated concepts in accelerated Phase I and II schedules. This topic is specifically aimed at later stage development rather than earlier stage basic science and research.

DESCRIPTION: The Air Force is a large and complex organizations that consists of many functions that have similar counterparts in the commercial sector. We are interested in exploring innovative technology domains that have demonstrated clear commercial value in the non-defense sector (i.e., through existing products/solutions) in order to see if they have similar Air Force applications (i.e. Dual-Purpose Technologies/Solutions). We recognize that it is impossible to cover every technological area with the SBIR topics, thus this topic is intended to be a call for open ideas and technologies that cover topics that may not be currently listed (i.e. the unknown-unknown). It is important that any potential solutions have a high probability of keeping pace with the technological change and thus should be closely tied to commercial technologies and solutions that will help support the development of the solution. This topic is meant for innovative non-defense commercial solutions to be adapted in innovative ways to meet DoD stakeholders' needs in a short timeframe and at a low cost. Solutions for this topic should be focused on the three areas listed below and should try to meet as many of these as possible. 1. Technical feasibility – There should be minimal technical risk to the overall solution. The best solutions will have demonstrated technical feasibility by showing the solution being used broadly by other customers, especially in the non-defense space. If the solution has not demonstrated technical feasibility in the non-defense space, the offeror(s) may provide alternative evidence to indicate technical feasibility such as initial lab tests, use of the product with defense customers and other forms of evidence. 2. Financial Sustainability – The offeror(s) should demonstrate financial sustainability of the solution and the offeror(s). The best solutions will demonstrate this by sales of the solution to non-defense clients and other sources of private investment. If the solution has not demonstrated financial sustainability by non-defense sales or private investment, the offeror(s) may provide other evidence of financial sustainability such as other governmental aid, sales to defense customers, and other forms of evidence that help explain the financial sustainability. 3. Defense Need – The offeror(s) should demonstrate that they have an understanding of the fit between their solution and defense stakeholders. The offeror(s) may provide an indication of a defense 'need' by evidence of preliminary discussions with USAF stakeholders, a clear description (including contact name, rank, unit and contact information) of a specific, potential USAF stakeholder that may need to use the solution or other forms of evidence to help explain a clear defense need. In summary - proposals for this topic should demonstrate a high probability to quickly find product-market fit between an Air Force end user and the proposed solution through adaptation of a non-defense commercial solution. This can be done through a proposal with a mature non-defense technical solution and a starting point to find an Air Force customer.

### BROAD FOCUS AREAS AND SPECIFIC USER NEEDS FOR 19.2 OPEN TOPIC

Though the topic is truly 'Open' (agnostic of industry, technology, and problem area), to facilitate streamlined customer discovery for companies in Phase I, we have identified certain problem areas for which potential Air Force Customers and/or funding have already been identified. These areas, which we break out into broad 'Focus Areas' and specific 'User Needs', are described below.

Focus Areas – for a broad 'Focus Area' to be included in this topic (the list of Focus Areas can be viewed at <https://www.afwerx.af.mil/sbir.html>), we required that it either have a significant number of Air Force customers seeking solutions in that area OR a specific Air Force Customer that has set aside funding to address that area by

way of SBIR fund-matching. Thus, if your solution can help address one of these Focus Areas, there is likely to be a good number of Air Force End-Users and customers that you can interact with in your phase I feasibility study and an increased likelihood for matching funding.

User Needs – for a specific ‘User Need’ to be included in this topic (the list of User Needs can be viewed at <https://www.afwerx.af.mil/sbir.html>), we required that an Air Force end-user or customer clearly articulate a specific problem affecting their mission for which they are actively seeking solutions from SBIR companies. Thus, if your solution can help address one of these User Needs, then there is \*at least\* one Air Force end-user that you can readily interact with in your phase I feasibility study.

If you believe your solution can help address one of the ‘Focus Areas or ‘User Needs’, please note this on the first slide of your application slide deck AND include the Focus Area ID # or User Need ID # in your ‘Keywords’ in the online SBIR application (Example: FA-001, or UN-1034).

The alignment between a proposal and a ‘Focus Area’ or ‘User Need’ can strengthen an application. Note that this does not change the requirement to demonstrate the defense need as listed above, but may complement it. This also does not preclude companies who are looking to solve other problems that are not listed in the ‘Focus Areas’ or ‘User Needs’ to submit to this topic; it is simply intended to give indications of areas of special focus for the Air Force at this particular point in time.

**PHASE I:** Validate the product-market fit between the proposed solution and a potential USAF stakeholder and define a clear and immediately actionable plan for running a trial with the proposed solution and the proposed AF customer. This feasibility study should directly address:

1. Clearly identify who the prime potential AF end user(s) and AF transition customer (the user and customer will likely be two different people) and articulate how they would use your solution(s) (i.e., the one who is most likely to be an early adopter, first user, and initial transition partner).
2. Deeply explore the problem or benefit area(s) which are to be addressed by the solution(s) - specifically focusing on how this solution will impact the end user of the solution.
3. Define clear objectives and measurable key results for a potential trial of the proposed solution with the identified Air Force end user(s).
4. Clearly identify any additional specific stakeholders beyond the end user(s) who will be critical to the success of any potential trial. This includes, but is not limited to, program offices, contracting offices, finance offices, information security offices and environmental protection offices.
5. Describe how the solution differs from the non-defense commercial offering to solve the Air Force need - (i.e. how has it been modified)
6. Describe the cost and feasibility of integration with current mission-specific products.
7. Describe if and how the demonstration can be used by other DoD or governmental customers. The funds obligated on the resulting Phase I SBIR contracts are to be used for the sole purpose of conducting a thorough feasibility study using scientific experiments, laboratory studies, commercial research and interviews. Prototypes may be developed with SBIR funds during Phase I studies to better address the risks and potential payoffs in innovative technologies.

**PHASE II:** Develop, install, integrate and demonstrate a prototype system determined to be the most feasible solution during the Phase I feasibility study. This demonstration should focus specifically on:

1. Evaluating the proposed solution against the objectives and measurable key results as defined in the phase I feasibility study.
2. Describing in detail how the solution differs from the non-defense commercial offering to solve the Air Force need and how it can be scaled to be adopted widely (i.e. how can it be modified for scale)
3. A clear transition path for the proposed solution that takes into account input from all affected stakeholders including but not limited to: end users, engineering, sustainment, contracting, finance, legal, and cyber security.
4. Specific details about how the solution can integrate with other current and potential future solutions.
5. How the solution can be sustainable (i.e. supportability)
6. Clearly identify other specific DoD or governmental customers who want to use the solution

**PHASE III DUAL USE APPLICATIONS:** This is the main goal of this topic, we intend for many of the solutions to go straight from Phase I to Phase III as soon as the product-market fit has been verified. The contractor will transition the adapted non-defense commercial solution to provide expanded mission capability to a broad range of potential government and civilian users and alternate mission applications.

NOTES:

- a. Due to the large amount of expected interest in this topic, we will not be answering individual questions through e-mail, except in rare cases. Instead we will be holding a teleconference to address all questions in an efficient manner. This topic will be updated with the final call-in details as soon as the date is finalized. In the meantime, feel free to use the SITIS Q&A system.
- b. This SBIR is NOT awarding grants, and is awarding contracts, when registering in SAM.gov, be sure to select 'YES' to the question 'Do you wish to bid on contracts?' in order to be able to compete for this SBIR topic. If you are only registered to compete for grants, you will be ineligible for this topic. For more information please visit <http://afwerxdc.org/sbir/>
- c. We are working to move fast, please register in SAMs and if already registered please double check your CAGE codes, company name, address information, DUNS numbers, ect. , If they are not correct at time of submission, you will be ineligible for this topic. In order to ensure this, please include, in your 15-slide deck, a screenshot from SAM.gov as validation of your correct CAGE code, DUNS number and current business address along with the verification that you are registered to compete for All Contracts. It is the responsibility of the contractor to ensure that the data in the proposal and the data in SAM.gov are aligned. For more information please visit <https://www.afwerx.af.mil/sbir.html>
- d. In order to keep pace with the fast timeline, if the purchase orders are not signed and returned to the contracting office within 5 business days of receipt, a Phase I award will not be issued.
- e. Please note that each company may only have one active 'Open Topic' award at a time. If a company submits multiple technically acceptable proposals, only the proposal with the highest evaluation will be awarded. If multiple proposals are evaluated to be equal, the government will decide which proposal to award based upon the needs of the Air Force. If a contractor is currently executing a Phase II award under the previous 'Open' topics (18.2-005, 18.3-005, 18.3-006, 19.1-004, 19.1-005), the company is ineligible for this topic. If the company applies for both the Direct to Phase II 'Open Topic' (192-D001) and this topic, and the company is selected for award for both topics, only the Direct to Phase II (192-D001) proposal will be awarded. All awards are subject to the availability of funds and contracting negotiations.
- f. The 'DoD SBIR/STTR Programs Funding Agreement Certification' form must be completed and signed at the time of \*Proposal Submission\* and can be found at: <https://www.afsbirstr.af.mil/Program/Phase-I-and-II/>.
- g. It is the responsibility of the contractor to answer the questions in the SBIR Cover Sheet and on the 'DoD SBIR/STTR Programs Funding Agreement Certification' accurately.
- h. While these are firm fixed price contracts, it is important for the companies to include the cost volume in the SBIR online application with reasonable fidelity in order to determine the reasonableness of the proposed effort. \*\*\*\*\*Proposals submitted under this topic may relate to technologies restricted under the International Traffic in Arms Regulation (ITAR) which controls defense-related materials/services import/export, or the Export Administration Regulation (EAR) which controls dual use items. Foreign National is defined in 22 CFR 120.16 as a natural person who is neither a lawful permanent resident (8 U.S.C. § 1101(a)(20)), nor a protected individual (8 U.S.C. § 1324b(a)(3)). It also includes foreign corporations, business associations, partnerships, trusts, societies, other entities/groups not incorporated/organized to do business in the United States, international organizations, foreign governments, and their agencies/subdivisions. Offerors must identify Foreign National team members, countries of origin, visa/work permits possessed, and Work Plan tasks assigned. Additional information may be required during negotiations to verify eligibility. Even if eligible, participation may be restricted due to U.S. Export Control Laws. NOTE: Export control compliance statements are not all-inclusive and do not remove submitters' liability to 1) comply with applicable ITAR/EAR export control restrictions or 2) inform the Government of potential export restrictions as efforts proceed.\*\*\*\*\*

#### REFERENCES:

1. FitzGerald, B., Sander, A., & Parziale, J. (2016). Future Foundry: A New Strategic Approach to Military-Technical Advantage. Retrieved June 12, 2018, from <https://www.cnas.org/publications/reports/future-foundry>
2. Blank, S. (2016). The Mission Model Canvas – An Adapted Business Model Canvas for Mission-Driven Organizations. Retrieved June 12, 2018, from <https://steveblank.com/2016/02/23/the-mission-model-canvas-an-adapted-business-model-canvas-for-mission-driven>
3. US Department of Defense. (2018). 2018 National Defense Strategy of the United States Summary, 11. Retrieved from <https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf>

4. AF192-001 SBIR 'Open Topic' Focus Areas – Retrieved from <https://www.afwerx.af.mil/sbir.html>
5. AF192-001 SBIR 'Open Topic' User Needs – Retrieved from <https://www.afwerx.af.mil/sbir.html>

KEYWORDS: Open, Other, Disruptive, Radical, Dual-Use, Commercial

TPOC-1: Chris Benson

AF192-005 TITLE: Kessel Run Pitch Day

TECHNOLOGY AREA(S): Cybersecurity, Data Communications

OBJECTIVE: This is a Pitch Day Topic, please see the above Pitch Day Topic instructions for further details. A Phase I award will be completed over 3 months with a maximum award of \$75K and a Phase II may be awarded for a maximum period of 15 (or 27 month) and \$750K. The objective of this topic is to explore innovative technologies that enable distributed business operations in challenging network environments and secure software and associated development environments against attacks, thus exploring options for innovative solutions that may fall outside the Air Force's current fields of focus but that may be useful to the US Air Force. This topic will reach companies that can complete a feasibility study and prototype validated concepts in accelerated Phase I and II schedules. This topic is specifically aimed at later stage development rather than earlier stage basic science and research. DESCRIPTION: The Air Force Program Executive Office for Digital is responsible for the acquisition of software and weapons systems including development and fielding worldwide aerospace command and control applications. The Air Force wishes to stay at the cutting edge of these technologies and seeks to partner with innovative small businesses that may have solutions to Air Force challenges. These are the high level challenge areas for which the Air Force is interested in novel solutions:

1. Security Tools and Services: Tools to monitor the security of unclassified software development environments, to include security of on premise and cloud-hosted applications, as well as technologies that enhance the security of software development systems, pipelines, and code repositories.
  2. Edge as a Service: Technologies to operate and maintain continuous and secure cloud-native operation in low-bandwidth environments.
  3. Enterprise Platform Tools: Technologies for enterprise platform design, development, and delivery, as well as technologies that facilitate application and infrastructure monitoring, API management and integration, legacy system virtualization and hosting, and container orchestrations and security.
- This topic is meant for innovative solutions to be adapted in innovative ways to meet DoD stakeholders' needs in a short timeframe and at a low cost.

PHASE I: "Validate the product-market fit between the proposed solution and a potential USAF stakeholder and define a clear and immediately actionable plan for running a trial with the proposed solution and the proposed AF customer. This feasibility study should directly address: 1. Clearly identify who the prime potential AF end user(s) is and articulate how they would use your solution(s) (i.e., the one who is most likely to be an early adopter, first user, and initial transition partner). 2. Deeply explore the problem or benefit area(s) which are to be addressed by the solution(s) - specifically focusing on how this solution will impact the end user of the solution. 3. Define clear objectives and measurable key results for a potential trial of the proposed solution with the identified Air Force end user(s). 4. Clearly identify any additional specific stakeholders beyond the end user(s) who will be critical to the success of any potential trial. This includes, but is not limited to, program offices, contracting offices, finance offices, information security offices and environmental protection offices. 5. Describe the cost and feasibility of integration with current mission-specific products. 6. Describe if and how the demonstration can be used by other DoD or governmental customers. 7. Describe technology related development that is required to successfully field the solution. 8. Deliver an initial prototype or minimum viable product (MVP) code or product at the conclusion of the contract that can be adapted and/or matured to a more advanced stage during Phase II. The funds obligated on the resulting Phase I SBIR contracts are to be used for the sole purpose of conducting a thorough feasibility study using scientific experiments, laboratory studies, commercial research and interviews.



Prototypes may be developed with SBIR funds during Phase I studies to better address the risks and potential payoffs in innovative technologies."

PHASE II: "Develop, install, integrate and demonstrate a prototype system determined to be the most feasible solution during the Phase I feasibility study. This demonstration should focus specifically on: 1. Evaluating the proposed solution against the objectives and measurable key results as defined in the phase I feasibility study. 2. Describing in detail how the solution can be scaled to be adopted widely (i.e. how can it be modified for scale) 3. A clear transition path for the proposed solution that takes into account input from all affected stakeholders including but not limited to: end users, engineering, sustainment, contracting, finance, legal, and cyber security. 4. Specific details about how the solution can integrate with other current and potential future solutions. 5. How the solution can be sustainable (i.e. supportability) 6. Clearly identify other specific DoD or governmental customers who want to use the solution"

PHASE III DUAL USE APPLICATIONS: "The Primary goal of SBIR is Phase III. The contractor will pursue commercialization of the various technologies developed in Phase II for transitioning expanded mission capability to a broad range of potential government and civilian users and alternate mission applications. Direct access with end users and government customers will be provided with opportunities to receive Phase III awards for providing the government additional research & development, or direct procurement of products and services developed in coordination with the program.

#### NOTES:

- a. Due to the large amount of expected interest in this topic, we will not be answering individual questions through e-mail, except in rare cases. Instead we will be holding a teleconference to address all questions in an efficient manner. This topic will be updated with the final call-in details as soon as the date is finalized. In the meantime, feel free to use the SITIS Q&A system.
- b. This SBIR is not awarding grants, but contracts, when registering in SAM.gov, be sure to select 'YES' to the question 'Do you wish to bid on contracts?' in order to be able to compete for this SBIR topic. If you are only registered to compete for grants, you will be ineligible for this topic.
- c. We are working to move fast, please register in SAMs and if already registered please double check your CAGE codes, company name, address information, DUNS numbers, ect. If they are not correct at time of submission, you will be ineligible for this topic. In order to ensure this, please include, in your 15-slide deck, a screenshot from SAM.gov as validation of your correct CAGE code, DUNS number and current business address along with the verification that you are registered to compete for All Contracts.
- d. Companies must be present at the Kessel Run Pitch event (July 2019 at the Kessel Run Software Factory located at 1 Beacon Street, Boston, MA) and complete their pitch to AF evaluators in order to receive an award.

#### REFERENCES:

1. "A Revolution in Acquisition and Product Support." Air Force Life Cycle Management Center, 2013, Retrieved 20 October from <https://www.wpafb.af.mil/Portals/60/documents/lcmc/LCMC-Revolution-in-Acquisition.pdf?ver=2016-07-01-110338-350>
2. "Air Force Life Cycle Management Center Homepage," Retrieved October 20 from <https://www.wpafb.af.mil/aflcmc/> "
3. "The Heilmeyer Catechism." DARPA, Retrieved October 24 from <https://www.darpa.mil/work-with-us/heilmeyer-catechism>

KEYWORDS: Software, development, Open-Source, sUAS, sensor

TPOC-1: Matt Brown  
Email: mbrown@kr.af.mil  
Phone: An Ask Me Anything Will Occur on May 1<sup>st</sup> and 13<sup>th</sup> in Lieu of Individual Conversations

AF192-006 TITLE: Unmanned Aerial Systems Pitch Day

TECHNOLOGY AREA(S): Unmanned Aerial Systems (UAS), Force Protection, Machine Learning/Artificial Intelligence, Autonomy, Open Systems

OBJECTIVE: This is a Pitch Day Topic, please see the above Pitch Day Topic instructions for further details. A Phase I award will be completed over 3 months with a maximum award of \$75K and a Phase II may be awarded for a maximum period of 15 (or 27 month) and \$750K. The objective of this topic is to explore innovative UAS and Counter-small UAS (C-sUAS) technologies that may not be covered by any other specific SBIR topic and thus to explore options for innovative solutions that may fall outside the Air Force's current fields of focus but that may be useful to the US Air Force. This topic will reach companies that can complete a feasibility study and prototype validated concepts in accelerated Phase I and II schedules. This topic is specifically aimed at later stage development rather than earlier stage basic science and research.

DESCRIPTION: This effort is a partnership between the Air Force Program Executive Office for Digital (PEO Digital), the Air Force Research Lab (AFRL), and the Tri-Service C-sUAS Swarm group. The Air Force PEO Digital is responsible for the acquisition of software and weapons systems including support for UAS air traffic avionics and control software, UAS applications to environmental sensing, and development of innovative C-sUAS technologies for defense of critical facilities. The AFRL leads the discovery, development and delivery of warfighting technologies for air, space and cyberspace forces including swarm autonomy and decision making, as well as open system approaches for UAS and subsystems like communications, human interfaces, and sensors, etc. The Air Force wishes to stay at the cutting edge of these technologies and seeks to partner with innovative small businesses that may have solutions to Air Force challenges. These are the high level challenge areas for which the Air Force is interested in novel solutions:

1. UAS payloads to defeat other UAS
2. UAS signature (optical, infrared, acoustic, radar, etc) identification software
3. UAS avionics open software trust and verification technologies
4. UAS sensing for weather hazard avoidance
5. UAS sensing for characterization of environmental conditions (wind, hydrology, RF spectrum, etc)
6. UAS sense and avoid technologies for operation in mixed manned/unmanned airspace
7. UAS applications to resilient PNT (mitigation of GPS degradation, etc)
8. Small UAS design assurance and airworthiness certification
9. Counter Swarm technologies
10. Agile technology insertion for UAS
11. Artificial intelligence and decentralized control for UAS swarms

This topic is meant for innovative solutions to be adapted in innovative ways to meet DoD stakeholders' needs in a short timeframe and at a low cost.

PHASE I: "Validate the product-market fit between the proposed solution and a potential USAF stakeholder and define a clear and immediately actionable plan for running a trial with the proposed solution and the proposed AF customer. This feasibility study should directly address:

1. Clearly identify who the prime potential AF end user(s) is and articulate how they would use your solution(s) (i.e., the one who is most likely to be an early adopter, first user, and initial transition partner).
2. Deeply explore the problem or benefit area(s) which are to be addressed by the solution(s) - specifically focusing on how this solution will impact the end user of the solution.
3. Define clear objectives and measurable key results for a potential trial of the proposed solution with the identified Air Force end user(s).
4. Clearly identify any additional specific stakeholders beyond the end user(s) who will be critical to the success of any potential trial. This includes, but is not limited to, program offices, contracting offices, finance offices, information security offices and environmental protection offices.
5. Describe the cost and feasibility of integration with current mission-specific products.
6. Describe if and how the demonstration can be used by other DoD or governmental customers.
7. Describe technology related development that is required to successfully field the solution.
8. Deliver an initial prototype or minimum viable product (MVP) code or product at the conclusion of the contract that can be adapted and/or matured to a more advanced stage during Phase II.

The funds obligated on the resulting Phase I SBIR contracts are to be used for the sole purpose of conducting a thorough feasibility study using scientific experiments, laboratory studies, commercial research and interviews. Prototypes may be developed with SBIR funds during Phase I studies to better address the risks and potential payoffs in innovative technologies."

PHASE II: "Develop, install, integrate and demonstrate a prototype system determined to be the most feasible solution during the Phase I feasibility study. This demonstration should focus specifically on: 1. Evaluating the proposed solution against the objectives and measurable key results as defined in the phase I feasibility study. 2. Describing in detail how the solution can be scaled to be adopted widely (i.e. how can it be modified for scale) 3. A clear transition path for the proposed solution that takes into account input from all affected stakeholders including but not limited to: end users, engineering, sustainment, contracting, finance, legal, and cyber security. 4. Specific details about how the solution can integrate with other current and potential future solutions. 5. How the solution can be sustainable (i.e. supportability) 6. Clearly identify other specific DoD or governmental customers who want to use the solution"

PHASE III DUAL USE APPLICATIONS: "The Primary goal of SBIR is Phase III. The contractor will pursue commercialization of the various technologies developed in Phase II for transitioning expanded mission capability to a broad range of potential government and civilian users and alternate mission applications. Direct access with end users and government customers will be provided with opportunities to receive Phase III awards for providing the government additional research & development, or direct procurement of products and services developed in coordination with the program. NOTES:

- a. Due to the large amount of expected interest in this topic, we will not be answering individual questions through e-mail, except in rare cases. Instead we will be holding a teleconference to address all questions in an efficient manner. This topic will be updated with the final call-in details as soon as the date is finalized. In the meantime, feel free to use the SITIS Q&A system.
- b. This SBIR is not awarding grants, but contracts, when registering in SAM.gov, be sure to select 'YES' to the question 'Do you wish to bid on contracts?' in order to be able to compete for this SBIR topic. If you are only registered to compete for grants, you will be ineligible for this topic.
- c. We are working to move fast, please register in SAMs and if already registered please double check your CAGE codes, company name, address information, DUNS numbers, ect. If they are not correct at time of submission, you will be ineligible for this topic. In order to ensure this, please include, in your 15-slide deck, a screenshot from SAM.gov as validation of your correct CAGE code, DUNS number and current business address along with the verification that you are registered to compete for All Contracts.
- d. Companies must be present at the UAS Pitch event (17 July 2019 at Northeastern University's Innovation Campus, Kostas Research Institute, in Burlington, MA) and complete their pitch to AF evaluators in order to receive an award.

#### REFERENCES:

1. "A Revolution in Acquisition and Product Support." Air Force Life Cycle Management Center, 2013, Retrieved 20 October from <https://www.wpafb.af.mil/Portals/60/documents/lcmc/LCMC-Revolution-in-Acquisition.pdf?ver=2016-07-01-110338-350>
  2. "Air Force Life Cycle Management Center Homepage," Retrieved October 20 from <https://www.wpafb.af.mil/aflcmc/> "
  3. "The Heilmeier Catechism." DARPA, Retrieved October 24 from <https://www.darpa.mil/work-with-us/heilmeier-catechism>
  4. U.S. Air Force, Small Unmanned Aircraft Systems (SUAS) Flight Plan: 2016-2036, 30 Apr 2016.
- KEYWORDS: Software, development, Open-Source, sUAS, sensor, weather, airworthiness, spectrum

TPOC-1: Nick Wasinger

Email: [nicholas\\_p.wasinger@us.af.mil](mailto:nicholas_p.wasinger@us.af.mil)

Phone: An Ask Me Anything Will Occur on May 1<sup>st</sup> and 13<sup>th</sup> in Lieu of Individual Conversations

AF192-007

TITLE: Standardized, Compact, and Automated Shock Tube for Fuel Characterization and Modeling

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: --

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

**OBJECTIVE:** The objective of this SBIR is to develop, Test and Validate a standardized, compact, automated and easy-to-use shock tube capable of state-of-art measurements of the ignition-delay-time and fuel pyrolytic and oxidation histories (optical and/or otherwise). The fuel pyrolytic and oxidation intermediate species measured are those involved in key combustion reaction pathways for AF and other DOD propulsion systems, and their measurement enables characterization of fuel combustion chemistry and supports combustion model development efforts.

**DESCRIPTION:** Fuel Combustion-chemistry properties determine molecular changes from high-energy-state fuel/oxidizer molecules to low-energy-state product molecules during the energy conversion process in AF and other DOD propulsion systems. Physically accurate and computationally efficient combustion chemistry models [1-3] are a critical part of physics-based modeling and simulation (M/S) tools for developing future generations of AF and other DOD propulsion systems such as solid/liquid rockets, aviation jet engines, and hypersonic scramjets. The capability of measuring fuel combustion chemistry properties such as the ignition delay and the fuel pyrolytic and oxidation intermediate species histories following key reaction pathways is a foundational element for the development and validation of such physically accurate and computationally efficient combustion chemistry models. Presently, the ignition delay and pyrolytic/oxidation species histories are mainly measured using shock-tubes equipped with start-of-art combustion diagnostic techniques (optical or intrusive probes) in research laboratories at leading universities. There are two long-lasting challenges: (1) non-standard facility/instruments and measurement procedures; and (2) expense in time and/or funding to operate such facilities. These shock-tube facilities and related combustion diagnostic instruments have been developed largely under incremental supports from AF (AFOSR) and other DOD 6.1 sources over the past several decades. Although the underlying scientific working principle has long been understood, due to the incremental nature of past development efforts in multiple universities by multiple agencies for different emphases, these facilities/instruments are of a research nature and not standardized, such that there are large variations in facility/instrumentation attributes. Comparing results from different facilities that use somewhat different procedures is often difficult. These facilities are usually expensive to operate, requiring long training times for graduate students or post-doc researchers to become proficient in facility and diagnostics operation. However, after many years of development, the shock-tube technology and associated combustion diagnostic techniques have matured sufficiently [4] to be standardized and transitioned for more applied uses (6.2 and beyond) at governmental research laboratories, such as AFRL, USAFA, or commercial aviation and aerospace industries, to support fuel characterization and fuel combustion-chemistry modeling. Furthermore, such standardized, compact and automated shock-tubes can be developed into a field deployable tool for fueling testing and quality control at fuel depots and major airports.

This topic focuses on the transition of the state-of-art research shock-tube setup along with necessary combustion diagnostic techniques to standardized, compact and easy-to-operate instrumentation tools with maximum automation for the fuel characterization and combustion chemistry model development. Proposals must include the all following aspects in an integrated fashion and will be evaluated accordingly: (1) Capable of measuring ignition delay and pyrolytic and oxidation intermediate species histories of sufficient temporal resolution with acceptable uncertainty; (2) Flow initiation process: diaphragm-less systems are highly desired/preferred. The valve opening time and the impact of valve opening process on the shock-propagating flow must be quantified to be adequate for the measurements mentioned above. For any flow initiation approaches, full impacts of the flow initiation process on the shock propagation flow must be sufficiently quantified for making proper measurements mentioned above. (3) The boundary-layer and other non-ideal flow attributes: proposed designs must be able to provide an adequate one-

dimensional shock-propagating core flow of sufficient size for the above mentioned measurements. Full impacts of the boundary layer and other non-ideal flow attributes must be sufficiently quantified. (4) Modular design and sufficient optical and probe accesses; and (5) Ease-of-use with maximum automation of operation and measurement processes suitable for laboratory technicians, without requiring highly-skilled research personnel.

PHASE I: Efforts consist of the following: (a) review state of art shock-tube technologies and associated diagnostic techniques, their capabilities, limitations and uncertainties with respect to earlier stated measurement objectives; (b) propose a creditable design and creditable quantification approaches with sufficient scientific and technical substantiations to address the above elements (1)-(5). A Phase I proposal will not be considered without clearly describing such creditable quantification approaches of sufficient details based on scientific and technical logic, especially for items (2) and (3) stated above; (c) incorporation of needed diagnostic techniques (optical, probes, etc.); (d) formulating a test/validation plan for measuring ignition delay time and key pyrolytic and oxidation species histories for small molecular foundational fuels (CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>3</sub>H<sub>8</sub> etc.) and real AF/DOD fuels/fuel blends including but not limited to JP8/Jet-A/JP5, JP10 and RP-2/its derivatives. The proper execution of Items (a)-(d) forms the foundation of the Phase II proposal. Phase I efforts consist of the following: (a) review state of art shock-tube technologies and associated diagnostic techniques, their capabilities, limitations and uncertainties with respect to earlier stated measurement objectives; (b) propose a creditable design and creditable quantification approaches with sufficient scientific and technical substantiations to address the above elements (1)-(5). A Phase I proposal will not be considered without clearly describing such creditable quantification approaches of sufficient details based on scientific and technical logic, especially for items (2) and (3) stated above; (c) incorporation of needed diagnostic techniques (optical, probes, etc.); (d) formulating a test/validation plan for measuring ignition delay time and key pyrolytic and oxidation species histories for small molecular foundational fuels (CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>3</sub>H<sub>8</sub> etc.) and real AF/DOD fuels/fuel blends including but not limited to JP8/Jet-A/JP5, JP10 and RP-2/its derivatives. The proper execution of Items (a)-(d) forms the foundation of the Phase II proposal.

PHASE II: Efforts focus on development and construction of prototype shock-tube system with the required diagnostic tools based on the Phase I design, and the execution of the test and validation plan developed in Phase I. Prototype systems will be delivered to DOD and/or other federal government laboratories and Institutions for testing usage.

PHASE III DUAL USE APPLICATIONS: Based on the inputs from the testing usage defined in Phase II, further improve the system capability and develop the system into field deployable systems for fueling testing and quality control at fuel depots and major airports.

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2. Wang, H., Xu, R., Wang, K., Bowman, C. T., Hanson, R. K., Davidson, D. F., Brezinsky, K., Egolfopoulos, F. N. "A Physics-based approach to modeling real-fuel combustion chemistry. I. Evidence from experiments, and thermodynamic, chemical kinetic and statistical considerations," *Combustion and Flame* 193, 502-519 (2018). DOI: 10.1016/j.combustflame.2018.03.019.
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4. Ronald Hanson and David Davidson, Recent advances in laser absorption and shock tube methods for studies of combustion chemistry, *Progress in Energy and Combustion Science* (2014) 44-1

KEYWORDS: Combustion chemistry, pyrolysis, shock-tube, ignition delay, pyrolytic pathways, aerospace propulsion systems

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AF192-008 TITLE: Millimeter wave Instrumentation and Characterization

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: --

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

OBJECTIVE: Broadband in-situ characterization of mm-wave components in vacuum

DESCRIPTION: Characterizing millimeter-wave electronic components in vacuum, such as slow-wave structures, antennas, amplifiers, and passive networks, is a crucial and largely unmet need, especially at affordable prices that would enable innovation in more laboratories. The established commercial approaches at lower frequencies use vector network analyzers; at frequencies well above 100 GHz, however, such instruments [1] are rare and prohibitively costly, and largely incompatible with vacuum equipment.

Transmission and reflection measurements from 50 to 500 GHz in vacuum conditions would enable testing of emerging millimeter and sub-millimeter-wave systems for space and vacuum electronic applications. Generation and detection of mm-wave test signals within the vacuum chamber would avoid lossy and expensive mm-wave hermetic links to bulky test equipment. While basic network analysis is a starting point, further refinements could include probe stations to hold devices under test and software to control and evaluate the data from the instrument.

The goal is a vacuum-compatible packaged mm-wave generation, detection, and probing platform for economical network analysis at mm-wave frequencies, up to and exceeding 500 GHz. For scalability, key manufacturing processes must be modified for wafer-scale processing compatibility.

Potential customers include Air Force research and university laboratories, start-up companies working in millimeter-wave systems and components, and established wireless companies, which need to characterize antennas, active devices and passive networks at frequencies above 50 GHz.

For example, the growth rate in 2020 for mm-wave amplifiers will exceed 10% given the explosive growth of 5G wireless systems using millimeter-waves.

PHASE I: Fabricate vacuum-compatible mm-wave network analysis probe head and demonstrate mm-wave characterization at atmosphere. Show that achieving network analysis measurements from 50 to 500+ GHz is feasible, and that probe cabling can transition into vacuum.

PHASE II: Fabricate vacuum feed-throughs for probe cabling, and test mm-wave probe characterization under vacuum. Further optimize signal generation and detection for higher frequencies.

PHASE III DUAL USE APPLICATIONS: Demonstrate key technology process optimizations for mass-production capability. Develop ancillary control and drive circuitry to move from lab prototype to commercial product.

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KEYWORDS: Vector Network Analysis, mm-Wave Characterization, mm-wave probes, vacuum electronics

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AF192-014 TITLE: RF Situational Awareness with Low-Cost Signal Samplers

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: GPS MGUE Inc2

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

OBJECTIVE: Develop and demonstrate a low SWaP-C network of RF spectrum awareness monitors that are able to navigate within, sense, share, and collectively characterize the local RF environment.

DESCRIPTION: Global positioning system (GPS) and Global Navigation Satellite System (GNSS) based receivers tasked to operate in urban areas do so in an increasingly densely populated RF environment. Due to the availability of low-power consumer-level jamming devices, and the complex reflection/attenuation nature of urban environments, the RF spectrum can vary widely both temporally and spatially. Recently, extremely low-cost digital video broadcast decoding devices containing the Realtek 2832U demodulator chip were found to allow access to raw inphase/quadrature (I/Q) 8-bit sample streams [1]. Capable of tuning ~50-1800 MHz, these sub-\$20 USB dongles enable software receiver processing of significant portions of the radio-navigation bands. A real-time GPS navigation solution has been demonstrated using this minimal hardware [2]. Utilizing an array of these sensing nodes will allow for a characterization of the local RF environment including localizing interference sources. Although each individual node captures and process only 2 MHz of spectrum [3] instantaneously, their low-cost and frequency agility, schemes of sweep patterns and/or multiple co-located nodes can be used to effectively cover large portions of spectrum. Spectrum snapshots (e.g. Fast Fourier Transform results or small amounts of raw signal samples) and location data can be conveyed to a master node in order to synthesize the RF environment characterization. In such a system, the various SatNav constellation band plans can be highlighted and selected for navigation based on

sensed spectrum conditions. Both ground and airborne nodes should be considered for this effort.

**PHASE I:** Study of algorithms and approaches that characterize the RF environments from distributed, frequency agile, narrow-band nodes. This includes determining types and amounts of data required to be transferred from multiple sensing nodes to a master node. Also required is a survey of RF propagation in urban areas to determine number of nodes required for situational awareness.

**PHASE II:** Develop a test plan and demonstrate RF environment characterization using a constellation of prototype nodes in a dense, urban area. Localize several strong signal sources for which location truth can be determined. Deliver RF sensing solution including communication infrastructure to government. Document design and test results in a final report.

**PHASE III DUAL USE APPLICATIONS:** Complete integration of receiving nodes and transmitting elements with custom circuit layouts. Ruggedize system, analyze power requirements, and determine suitable portable power sources.

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**KEYWORDS:** GPS, software radio, spectrum sensing, situational awareness

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AF192-015            TITLE: Low SWAP-C Anti-Jam Techniques for MGUE Increment 2 Handheld Receiver

**TECHNOLOGY AREA(S):** Sensors

**ACQUISITION PROGRAM:** GPS MGUE Inc2

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

**OBJECTIVE:** Identify and research passive and active low size, weight, power, and cost AJ techniques, technologies, and/or algorithms that can be integrated with and meet the SWAP-C constraints of the projected MGUE Increment 2 handheld receiver.



DESCRIPTION: Anti-jam (AJ) research for GPS User Equipment has primarily been focused on producing high-performance systems that are targeted for aircraft, ship, and missile platforms operating in highly stressed Electronic Warfare (EW) environments. Controlled Radiation Pattern Antennas (CRPAs), combined with antenna electronics, have evolved to provide very high anti-jam nulling capability and high-gain beam-steering. However, the SWAP-C of these high-end systems put this capability out of reach for many users including the dismounted soldier and ground vehicles using handheld receivers like DAGR and PLGR. This large user base requires a higher level of AJ protection than is currently provided by the receivers internal GPS signal acquisition and tracking implementations to meet mission objectives in a highly contested EW environment. Previous techniques were explored to enhance handheld AJ protection, such as a two-element nulling antenna accessory that could be externally attached to the handheld receiver. However, the SWAP of some of these techniques made them operationally cumbersome from a user perspective or provided only a marginal increase in AJ protection.

Under the MGUE Increment 1 program, several techniques were developed under the Resiliency and Software Assurance Modification (RSAM) effort to enhance AJ performance of MGUE Increment 1 receivers. While these techniques are expected to transition to the MGUE Increment 2 modernized GPS handheld receiver, they will not provide the full level of AJ protection for dismounted operations in the projected EW environment. The Increment 2 handheld receiver effort is currently in the requirements definition phase. The initial SWAP constraints for this receiver are 35 cubic inches volume, 450 grams weight, and 19 hours of continuous use without battery change.

This SBIR will identify and evaluate the performance and implementation of low-SWAP-C AJ techniques, including mechanical, passive, active and or algorithmic techniques, that are compatible with the MGUE Increment 2 handheld receiver SWAP constraints. The objective is to increase the AJ protection by at least 20 dB over that currently projected for the receiver itself. AJ capability should be based on scenarios consisting of multiple mobile and stationary ground-based jammers in an urban environment. Emphasis should be placed on solutions that are achievable by receiver developers (such as the MGUE Increment 1 prime contractors). The primary goal is to provide a comparative evaluation of multiple techniques, including performance, size, weight, and power and operational suitability assessments and implementation cost and prototype a sub-set of promising techniques.

Offerors are encouraged to work with MGUE Increment 1 prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerors should clearly indicate in their proposals what government furnished property or information are required for effort success.

PHASE I: Conduct a comprehensive comparative assessment of low SWAP-C AJ techniques that are compatible with the SWAP constraints of the projected MGUE Increment 2 handheld to include AJ effectiveness, operational suitability, and size, weight, power, and cost.

PHASE II: Since a physical implementation of the handheld receiver does not currently exist, design and implement a brassboard or prototype for one or two of the most promising low SWAP-C techniques using, as examples, a SWAP-compatible physical mock-up of the projected receiver and/or COTS development boards implementing M-code acquisition and tracking algorithms. The Phase 2 effort should include ensuring compatibility with interface requirements currently specified for the Increment 2 handheld receiver.

PHASE III DUAL USE APPLICATIONS: With an MGUE Increment 2 vendor, integrate the selected SWAP-C AJ techniques demonstrated in Phase II with an Inc2 handheld prototype. Demonstrate the capability to meet performance and SWAP-C requirements. Identify transition opportunities for civilian applications such as those performed by DHS.

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KEYWORDS: 1. Anti-Jam  
2. MGUE Increment 2  
3. GPS Modernized Handheld

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AF192-016            TITLE: Heterogenous Power Exploitation in GPS Receivers

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: GPS MGUE Inc2

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

OBJECTIVE: Identify, evaluate, and demonstrate techniques for receivers to use one or a small number of higher power M-code signals to substantially improve jamming tolerance, relative to that without the higher power signals.

DESCRIPTION: Heterogeneous Power Exploitation (HPE) allows GPS receivers to more fully benefit from a small number, as few as one, of higher power signals when the others are lower power. HPE involves a combination of signal use logic (smartly selecting higher power signals for acquisition and tracking) as well as advanced signal processing techniques that use the more robust higher power signals to aid tracking of less robust, lower power signals. For the foreseeable future, the GPS constellation will provide a range of received M-code power levels. Even the mix of Block II satellites and early GPS III satellites will provide received M-code power levels varying by more than 12 dB, not accounting for variations in receive antenna gain. With regional military protection (RMP) or higher power hosted quasi M (QM)-signals, the variation in received signal power levels could approach 25 dB. Current receivers are not specified or tested to fully benefit from the higher power signals. Research and development is needed to identify and demonstrate practical and effective techniques for HPE. The objective should be receiver processing techniques and approaches that use one or a small number of higher power signals to substantially improve jamming tolerance, relative to that without the higher power signals.

PHASE I: The first phase will focus on the identification of receiver-based techniques to exploit the HPE and initial performance evaluation. Candidate techniques can be identified via literature review and/or invented by the performers. Once identified these techniques will be initially evaluated (e.g. via software simulation) to quantify their relative performance improvement. Recommendations will be made as to which techniques should be

implemented in hardware as part of Phase II. Approaches and techniques should provide trade-off analyses including performance gain versus implementation complexity (e.g. power, SLOC, etc.)

PHASE II: The second phase will focus on selective implementation of the best techniques identified in Phase I. These should be implemented in a real-time GPS receiver to allow for hardware-in-the-loop (HITL) testing. Once implemented the performance of these techniques will be evaluated over a range of situations (GPS constellation power levels, user state, user dynamics, etc.)

PHASE III DUAL USE APPLICATIONS: The third phase will transition the capability to contractors for potential implementation in military GPS User Equipment. In addition, this phase could explore the techniques for applicability to civilian signals (e.g. L1C/A, L1C, L2C, and L5) to improve signal performance in jamming conditions since 5-10 dB variation in gain of these signals can be expected from fixed-radiation pattern antenna receive antennas.

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KEYWORDS: Global Positioning System, M-Code, MGUE, Vector Delay Lock Loop

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AF192-017 TITLE: W-band Receive Phased Array for SATCOM Uplinks

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: --

OBJECTIVE: Develop innovative wafer-scale antenna and front-end components for a multi-element receive phased array for future W-band SATCOM uplinks.

DESCRIPTION: Future military SATCOM concepts include V-band (71-76 GHz) downlinks and W-band (81-86 GHz) uplinks to support next-generation high-data-rate communications systems. These systems will extend to new SATCOM frequency spectrums to address frequency crowding at lower frequencies. Additionally, currently demonstrated array front-end components at these frequencies have relatively low output power. Further, while single-point RF receivers with gimbaled antennas address a potential W-band receiver architecture, phased array architectures are also viable for these satellite communications concepts. This Phase I SBIR focuses on defining advanced architecture and performance goals for a communications W-band receive phased array, designing wafer-scale antenna and front-end components, and defining a proof-of-concept multi-element demonstration vehicle. At a minimum, the array components/functions should include multi-beam, multi-channel receiver. Due to high atmospheric propagation at these frequencies, ultra-low noise amplifier and low power consumption technology and should be considered. Further,  $\pm 9$  degree scanning angles and 0.1 degree 3-dB-beamwidths should be included in the phased array architecture definition. Operating environment goals include a temperature range of -40 degrees to

+85 degrees Celsius. The selected solid-state technologies should also support reliable space operation and operation in radiation environments. Radiation hardening goals include greater than 1 Mrad total dose radiation tolerance.

PHASE I: Definition of the W-band phased array receiver architecture and performance goals, definition of a multi-element demonstration vehicle, and the design of required antenna and front-end components.

PHASE II: Development and demonstration of the wafer-scale antenna and front-end components, as well as the multi-element W-band receive phased array designed in Phase I.

PHASE III DUAL USE APPLICATIONS: Links technologies under this effort will further benefit applications in nearby frequency bands. Military: Military millimeter-wave phased array applications include W-band satellite communications uplink electronics for future high-data-rate communications systems.

Commercial: Commercial W-band phased array applications potentially include commercial satellite communications services and 5G backhaul communication .

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KEYWORDS: W-band, low noise amplifier, satellite communications

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AF192-018 TITLE: Dual-Band, Multi-Platform High Power Amplifiers for SATCOM Uplinks

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: --

OBJECTIVE: Develop dual-band, linear-efficient high power amplifiers for cost-effective, multi-platform satellite communication uplinks.

DESCRIPTION: The Air Force is interested in developing a new generation of dual-band, linear-efficient high power amplifiers to replace airborne and ground platform amplifiers that singularly address either Ka-band or Q-band operation. This development complements a current dual-band Ka/Q-band low noise amplifier development for the space segment. The innovatively-designed, multi-band power amplifier is expected to have applicability to cost-effective, multi-platform SATCOM uplink transmitter applications. This includes future frequency hopping applications for airborne platform-based uplinks in advanced SATCOM concepts. The performance goal for the dual-band HPA is power gain optimized in the 29.0-31.0 GHz band, as well as 43.5-45.5 GHz frequency band, with suppressed gain at the interim frequencies. Potential millimeter-wave power amplifier approaches may include solid-state power amplifiers (SSPAs) or traveling wave tube amplifiers (TWTAs). At the subcomponent level,

various solid-state transistor, power combiner, and traveling wave tube approaches are feasible towards the integrated SSPA or TWTA. The research conducted under this topic should address the dual-band Ka/Q-band performance goals of greater than 100-watt output power, greater than 30% power-added efficiency (PAE), a minimum of 30 dB power gain and an operating temperature range of -40° to + 80° Centigrade. In general, power amplifier efficiency translates to dc power consumption requirements for electronics, as well as additional hardware to address corresponding cooling requirements. Further, linear performance should, at a minimum, address QPSK and 8PSK operation.

**PHASE I:** Design dual-band Ka/Q-band high power amplifiers consistent with the performance goals and objectives identified above. Perform additional validation of the designs through modeling and simulation.

**PHASE II:** Fabrication of the Phase I-designed subcomponents and their assembly into integrated high power modules, either solid-state power amplifier or traveling wave tube amplifier prototype(s). Evaluation and characterization of the prototype(s) for all relevant performance parameters.

**PHASE III DUAL USE APPLICATIONS:** Military: Military high power amplifier applications include Ka-band and Q-band communications uplink electronics for Wideband Global SATCOM (WGS) and Advanced Extremely High Frequency (AEHF) systems.

Commercial: Commercial Ka/Q-band high power amplifier applications include ground/airborne electronics where millimeter-wave power sources are required.

#### REFERENCES:

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2. J. Browne, TWTA's Power Satcom Systems, Microwaves and RF, April 2012.
3. N. Escalera, et al., Ka-Band 30 Watts Solid State Power Amplifier, Microwave Symposium Digest, 2000 IEEE MTT-S International, pp. TUIF-42:561-563, 2000.
4. X. Yu et al., "A Millimeter Wave 11W GaN MMIC Power Amplifier", Proc. Asia-Pacific Conf. on Antennas and Propagation (APCAP), pp. 1342-1344, 2014.

**KEYWORDS:** Traveling Wave Tube Amplifier, Solid-State Power Amplifier, satellite communications, Ka-band, Q-band

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AF192-019            TITLE: V-band Transmit Phased Array for SATCOM Downlinks

**TECHNOLOGY AREA(S):** Sensors

**ACQUISITION PROGRAM:** --

**OBJECTIVE:** Develop innovative wafer-scale antenna and front-end components for a multi-element transmit phased array for future high-power V-band SATCOM downlinks.

**DESCRIPTION:** Future military SATCOM concepts include V-band (71-76 GHz) downlinks and W-band (81-86 GHz) uplinks to support next-generation high-data-rate communications systems. These systems will extend to new SATCOM frequency spectrums to address frequency crowding at lower frequencies. Additionally, currently demonstrated array front-end components at V-band have relatively low output power. Further, while single-point RF power sources with gimbaled antennas address a potential V-band transmitter architecture, phased array architectures are also viable for these satellite communications concepts. This Phase I SBIR focuses on defining

advanced architecture and performance goals for a communications V-band downlink transmit phased array, designing wafer-scale antenna and front-end components, and defining a proof-of-concept multi-element demonstration vehicle. At a minimum, the array components/functions should include power amplification and beam steering. Due to high atmospheric propagation at these frequencies, EIRP >100 watts and per element power output >400 mW should be considered. However, thermal management feasibility should be evaluated. Further,  $\pm 9$  degree scanning angles and 0.1 degree 3-dB-beamwidths should be included in the phased array architecture definition. Operating environment goals include a temperature range of -40 degrees to +85 degrees Celsius. The selected solid-state technologies should also support reliable space operation and operation in radiation environments. Radiation hardening goals include greater than 1 Mrad total dose radiation tolerance.

PHASE I: Definition of the V-band phased array architecture and performance goals, definition of a multi-element demonstration vehicle, and the design of required antenna and front-end components.

PHASE II: Development and demonstration of the wafer-scale antenna and front-end components, as well as the multi-element V-band transmit phased array designed in Phase I.

PHASE III DUAL USE APPLICATIONS: Military: Military millimeter-wave phased array applications include V-band satellite communications downlink electronics for future high-data-rate communications systems. Commercial: Commercial V-band phased array applications potentially include commercial satellite communications services. Technologies under this effort will further benefit applications in nearby frequency bands.

#### REFERENCES:

1. S. Zehir, et al., A 60 GHz 64-element Phased-Array Beam-Pointing Communication System for 5G 100 Meter Links up to 2 Gbps, 2016 IEEE MTT-S International Microwave Symposium.
2. K. Tsukashima, et al., An E-band 1 W-class PHEMT Power Amplifier MMIC, Microwave Integrated Circuits Conference Digest, 2015 10th European Microwave Integrated Circuits Conference.
3. A. Brown, et al., High Power, High Efficiency E-Band GaN Amplifier MMICs, Wireless Information and Systems Digest, 2012 IEEE International Conference on Wireless Information Technology and Systems.
4. . Shahramian ; M. J. Holyoak ; Yves Baeyens, A 16-Element W-Band Phased-Array Transceiver Chipset With Flip-Chip PCB Integrated Antennas for Multi-Gigabit Wireless Data Links, IEEE Transactions on Microwave Theory and Techniques, 2018

KEYWORDS: E-band, V-band, phased arrays, satellite communications

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AF192-020 TITLE: V-Band Crosslink Solid-State Power Amplifiers

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

OBJECTIVE: Development of compact, lightweight high-power solid-state power amplifiers for V-band crosslinks.

DESCRIPTION: Compact 59-65 GHz crosslink solid-state power amplifiers (SSPAs) are required to meet future millimeter-wave satellite communications transmit power requirements. Today's high-power-density technologies offer significant output power increases over currently-fielded solid-state device technologies and solutions. These device technologies, coupled with innovative power combining, are expected to provide unmatched millimeter-wave power performance in compact form factors, providing increased transmit power and range benefits without

increasing satellite size and weight requirements. Potential approaches for linear-efficient V-band solid-state power performance should address both the high-performance millimeter-wave transistor, innovative circuit approaches, and compact low-loss power combiner approaches. The SSPA's performance goals include simultaneous >50-watt output power, >30 dB power gain with gain variation less than  $\pm 1$  dB, and >25% power-added efficiency performance across 59-65 GHz. The SSPA's AM-to-PM performance should reflect <5 degrees/dB through 50-watt output operation. Additional goals include an operating temperature range of -40 degrees to +85 degrees Celsius. The selected solid-state power amplifier approach should support reliable space operation and operation in radiation environments. Radiation hardening goals include greater than 1 Mrad total dose radiation tolerance.

PHASE I: Concept design and circuit simulations of the linear-efficient 59-65 GHz microwave monolithic integrated circuit (MMIC) power amplifier based on a suitable, high-performance millimeter-wave transistor process, as well as the integrated design of the power-combined SSPA.

PHASE II: Fabrication of the linear-efficient prototype power amplifiers (MMICs, power combiner, integrated SSPA) according to the Phase I design. Characterization of the MMICs, combiner and SSPA for linearity, output power, and efficiency under typical signal and environmental conditions.

PHASE III DUAL USE APPLICATIONS: Military: Military high power amplifier applications include V-band satellite communications crosslink electronics for systems such as Advanced EHF.

Commercial: Commercial V-band high power amplifier applications include ground/airborne/space electronics where millimeter-wave power sources are required. Technologies and methodologies under this effort will further benefit commercial communication networks in nearby frequency bands.

#### REFERENCES:

1. K. Tsukashima, et al., An E-band 1 W-class PHEMT Power Amplifier MMIC, Microwave Integrated Circuits Conference Digest, 2015 10th European Microwave Integrated Circuits Conference.
2. A. Brown, et al., High Power, High Efficiency E-Band GaN Amplifier MMICs, Wireless Information and Systems Digest, 2012 IEEE International Conference on Wireless Information Technology and Systems.
3. J. Cheron et al., "High-Efficiency Power Amplifier MMICs in 100 nm GaN Technology at Ka-Band frequencies", Proc. Eur. Microw. Integ. Circuits Conf. (EuMIC), pp. 492-495, 2013.
4. C.F. Campbell et al., "High Efficiency Ka-Band Power Amplifier MMICs Fabricated with a 0.15 um GaN on SiC HEMT Process", IEEE MTT-S Int. Dig., pp. 1-3, Jun. 2012.

KEYWORDS: V-band crosslinks, solid-state power amplifier, power-added efficiency, satellite communications

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AF192-021 TITLE: High Spectral Resolution Longwave Infrared Hyperspectral Imaging System

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: N/A

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions.

Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct ITAR specific questions to the AF SBIR/STTR Contracting Officer, Ms. Michele Tritt, michele.tritt@us.af.mil.

**OBJECTIVE:** Develop a high spectral resolution longwave infrared hyperspectral sensor suitable for low-to-medium altitude airborne intelligence, surveillance, and reconnaissance.

**DESCRIPTION:** Airborne hyperspectral imaging (HSI) sensors have demonstrated utility for material detection and identification. Additionally, longwave infrared (LWIR) HSI systems can operate day/night and can be used to monitor gaseous effluents as many gases possess strong spectral features within the 7-14um spectral range. Existing dispersive systems demonstrate excellent radiometric performance but are generally limited in spectral resolution due to the relatively small format of available focal plane array (FPA) technology [1]. Fourier transform infrared (FTIR) systems can achieve high spectral resolution but at the expense of added collection time. For airborne platforms, this added time places too much demand on pointing and stabilization to prevent spectral artifacts. As next generation very longwave infrared (VLWIR) FPAs with small pitch, large format, and extended spectral range become available [2], next generation LWIR HSI sensors can potentially be developed capable of collecting with high spectral resolution while maintaining sufficient radiometric performance and collection time. This effort will produce a high spectral resolution LWIR HSI sensor with >400 (T) (500 (O)) bands over a spectral range of 8.0-12.5um (T) (8.0-13.0um (O)) with <12nm (T) (<10nm (O)) spectral resolution measured as full-width half max (FWHM). Additionally, the sensor must be able to collect a spatial scene of >400x400 pixels in <2s while maintaining a noise-equivalent spectral radiance (NESR) of < 2uW/(cm2-sr-um) (T) (< 1uW/(cm2-sr-um) (O)), while viewing a 300K blackbody source. Optical distortions, such as smile and keystone, will be maintained to <1/8 of a channel.

**PHASE I:** This effort will develop candidate designs and evaluate available FPA technology. A full system model will be developed to determine expected performance of the system in terms of spectral sampling, spectral resolution (full-width half max), smile, keystone, and NESR for expected frame rate and exposure time of the system.

**PHASE II:** The effort will refine the design as needed, procure materials and equipment, and build the system. The system will be fully characterized in a laboratory to measure spectral resolution, spectral smile, keystone, and spectral NESR. Additionally, tower testing of the instrument will occur with relevant field targets to demonstrate imaging performance and spectral exploitation. Government equipment and labs may be used in support of system testing and characterization.

**PHASE III DUAL USE APPLICATIONS:** Phase 3 will refine the design based on outcomes of tests and customer feedback in Phase 2. The system will be flight tested and further integrated into a relevant pod given customer interest.

**REFERENCES:**

1. J. Hall, et al, "Mako airborne thermal infrared imaging spectrometer – performance update," Proc. SPIE, 9976, 997604-1 – 997604-9, (2016)
2. H. Figgemeier, et al, "State of the Art of AIM LWIR and VLWIR MCT 2D Focal Plane Detector Arrays for Higher Operating Temperatures," Proc. SPIE, 9819, 98191C-1 – 98191C-16, (2016)

**KEYWORDS:** Longwave infrared, hyperspectral imaging, sensor

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AF192-022                      TITLE: Develop Small Pitch Geiger Mode Avalanche Photodiode Detector Arrays for Multifunction LiDAR Receivers



TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: Next Generation Sensors for Airborne ISR

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

**OBJECTIVE:** Design, fabricate, and test small format GMAPD arrays for multifunction LiDAR cameras operating in direct detection and coherent sensing applications supporting Global Precision Attach (GPA) or Globally Integrated Intelligence Surveillance and Reconnaissance (GIISR) mission types. The arrays will operate at a 2 um wavelength, capable of operating without sizable cooling requirements with a goal of room temperature operation.

**DESCRIPTION:** Recent advances in semiconductor development for Geiger mode avalanche photodiode (GMAPD) light detection and ranging (LiDAR) readout integrated circuits (ROIC) have provided means to reduce effective area of an individual pixel through improvements in detection circuit design and smaller semiconductor design rules. Typical SWIR detector designs for imaging LiDAR sensors operate below 1.7 um wavelengths, except for few designs which incorporate cryogenic cooling in order to maintain detection sensitivity. This topic seeks to develop small pitch, large format detector arrays capable of operating at a 2 um wavelength, with LiDAR functionality, without the need for physically sizable cooling. Thermoelectric cooling may be implemented for temperature control, with a goal of > 250 °K operating temperatures. Detector development should include physics-based modeling of the device structure in order to determine performance expectations and to aid in camera component development. Iterative design experiments are expected in order to yield insight into device physics. The detector arrays should be of a 32 x 32 format and scalable to larger formats, arrays with pixel pitch of 100 um with additional arrays of 50 um pitch and scalable to smaller pixel pitch, electrical connection at the pixel level with a metal pad on the APD, common anode or common cathode connections along 2 sides of the array, capable of operation at < 5 V above breakdown, capable of conducting pixel current while minimizing crosstalk and other noise effects across the array, and maximizing effective quantum efficiency. Laboratory testing of the detector arrays will be necessary in order to determine sensitivity and noise performance, and characterization of arrays' performance is required. The detector arrays may be bonded to existing ROICs in order to fabricate laboratory-class LiDAR receivers, and provide a path toward fabrication of large format LiDAR receivers. Bonding of the detector arrays to fanout test fixtures and characterization of the detectors is desired.

The following are design goals for a full receiver: LiDAR functionality, detection wavelength between 2.0 to 2.1 um, single photon detection, low dark count rate, operability of > 99%, nominal probability of detection (PDE) of ≥ 25% at a corresponding dark count rate of < 100 kHz with goal of < 10 kHz, uniformity of PDE and DCR across the array, sample bin interval of less than 1.5 nsec for direct detection modes, minimal quench and rearm duration supporting asynchronous operation in Geiger mode, and the ability to operate without cryo-cooling. The goal of the effort is to develop detectors for a Geiger mode LiDAR system which would provide data to generate 3-D point clouds and other data products. Detector cooling and power requirements can drive CSWaP of a full camera. Cooling, size, weight, and power (CSWaP) for the receiver would need to be considered for the final design, where insertion into a small UAV, existing targeting pod, or turret as a goal. Government furnished equipment is not required for this project.

**PHASE I:** Develop design ideas for detectors, APD arrays, laboratory test configurations, and test plans for characterization of the devices. Develop a program plan, SOW, and performance expectations for the small format receiver in Phase II. Develop a commercialization plan.

**PHASE II:** Design, fabricate, test and characterize small (32x32) format detector arrays incorporating 100 um pitch and 50 um pitch detectors. Provide laboratory test results, details of test methods. Deliverables include small format detector arrays with supporting electronics for laboratory testing. Develop a program plan, SOW, and

performance expectations for a LiDAR receiver capable of insertion into SUAV's, targeting pod, or turret.

PHASE III DUAL USE APPLICATIONS: Design, develop, and test a LiDAR receiver capable of flight testing in an airborne laboratory type environment. Develop a program plan to integrate into an aerial platform and perform flight testing. Work with a system integrator to integrate into surrogate test platform, and perform flight demonstrations.

REFERENCES:

1. E. Duerr, et. al., "Antimonide-based Geiger-mode Avalanche Photodiodes for SWIR and MWIR Photon-counting", Proc. SPIE 7681, Advanced Photon Counting Techniques IV, 76810Q (28 April 2010)
2. J. Campbell, "Recent Advances in Avalanche Photodiodes", IEEE Journal of Lightwave Technology Vol. 34, 6 July 2015
3. Mark A. Itzler ; Mark Entwistle ; Mark Owens ; Ketan Patel ; Xudong Jiang ; Krystyna Slomkowski ; Sabbir Rangwala ; Peter F. Zalud ; Tom Senko ; John Tower ; Joseph Ferraro; Design and performance of single photon APD focal plane arrays for 3-D LADAR imaging. Proc. SPIE 7780, Detectors and Imaging Devices: Infrared, Focal Plane, Single Photon, 77801M (August 17, 2010)
4. R. Sidhu, L. Zhang, N. Tan, N. Duan, J.C. Campbell, A.L. Holmes, Jr., C.-F. Hsu and M.A. Itzler, "2.4  $\mu$ m cutoff wavelength avalanche photodiode on InP substrate", IEEE Electronics Letters Vol. 42, 2 Feb. 2006

KEYWORDS: LADAR, LiDAR, APD, Geiger mode lidar

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AF192-023 TITLE: Conformal Beam Steering for High Resolution Ladar

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop conformal optical steering system for a LADAR sensor suitable for scaling via tiling small sub-apertures to realize larger, meter class apertures with low size, weight, and power. This device should be amenable for steering the field of view (FOV) of a high-resolution LADAR imaging receiver.

DESCRIPTION: The Air Force has pressing requirements for operating in contested environments where intelligence, surveillance, and reconnaissance (ISR) assets cannot operate freely. The Air Force requires high confidence ID for high value targets to protect air crews and to establish air superiority. Two approaches considered are deployment of large aperture sensors, such as LADAR, to provide stand-off imaging capability, and use of attritable, unmanned aerial systems (UAS) for penetrating ISR and strike. Both approaches need enhanced target ID capabilities of LADAR as well as persistent passive imaging via mid-wave or long-wave imaging for cueing and situational awareness.

Conventional optical systems rely on gimbaled optics, which significantly limit the aperture size and increase Cost, Size, Weight and Power (C-SWAP). For large apertures, the pod cannot physically accommodate the gimbal size required and a conformal approach is the only way forward. The attritable platform has tight C-SWAP restrictions, which imposes severe performance trades for gimbaled approaches.

Non-mechanical beam steering (NMBS) is a technology that provides the ability to direct a laser beam without physical movement of the optical elements. NMBS offers performance advantages over mechanical systems with reduced weight, random access to steering directions, expanded field of view (FOV), and higher steering speeds. In

addition NMBS offers logistical advantages, with electronic optical calibration, high precision and accuracy, and sealed long life components. NMBS devices have been developed that steer to discrete points at high efficiency using a stack of polarization gratings, or addressable points with a single optical phased array (OPA).

The goal of this effort is to demonstrate a conformal optical steering system that steers 2 micron light. The steering system should use smaller sub-apertures with a well-defined optical phase relation between them to create larger effective apertures. This technique is meant to create an essentially scalable fabrication method for realizing arbitrarily larger effective apertures up to at least 6 inches diameter with a goal of up to 12 inches diameter. For example, the use of nanophotonic optical elements, or metasurfaces, for creating engineered optical properties of light has been shown to be a versatile technique for beam shaping, but methods for scaling this to larger apertures remains a challenge. This and other approaches for beam steering or shaping will be considered, with an emphasis on techniques which can be readily scaled to larger sizes through repeated patterning of smaller sub-apertures.

The final steering system should be capable of steering to  $>(\pm)15$  degrees in one dimension, (goal  $(\pm)30$  degrees), with  $>80\%$  power in steered beam. Devices should operate at  $>200\text{Hz}$ , with a goal of 1 kHz operation.

Commercial application of a conformal low C-SWAP optical steering would have similar benefits for civil uses of LADAR mapping. Government materials, equipment, data or facilities are not necessary.

**PHASE I:** In this initial phase, device concepts will be developed, evaluated, and computer modeled. Design challenges and trade-offs will be tabulated and areas in need of additional R&D will be identified. Critical factors to consider are, maximum theoretical transmission, aperture size, low SWAP packaging, and demonstrating that the technology can achieve requirements through models. SWaP guidelines to consider include the potential for aperture sizes from 6 inches up to about 40 inches in diameter, weight under 5 kilograms, and average power usage under 10 W. Preliminary designs should be developed for Phase II.

**PHASE II:** Devices will be constructed and tested for beam steering efficiency, aperture, and SWAP requirements. Tests will be conducted to verify performance parameters of the device with a short-wave infrared camera surrogate for a LADAR. Iteration on designs and improvements will be made as the production process is refined and preliminary designs for a Phase III device should be made.

**PHASE III DUAL USE APPLICATIONS:** A flight ready version of the design will be built, steering efficiencies, and size, weight and power of both device and control system in form factor for integration in a UAS. Current manufacturing process will be evaluated and refined to improve yield while reducing cost.

#### REFERENCES:

1. Optical Phased Array Technology, Paul F. McManamon et. al., Proceedings of the IEEE, Vol. 84, No. 2, February 1996.
2. High-Efficiency All-Dielectric Metasurfaces for Ultracompact Beam Manipulation in Transmission Mode, Mikhail I. Shalaev et. al., Nano Letters, 15 (9), pp 6261–6266 (2015)
3. Large area metalenses: design, characterization, and mass manufacturing, Alan She et. al., Optics Express Vol. 26, No. 2 pp. 1573-1585, (2018)
4. Wide-Angle, Nonmechanical Beam Steering Using Thin Liquid Crystal Polarization Gratings, Jihwan Kim et. al., Advanced Wavefront Control: Methods, Devices, and Applications VI, Proc. of SPIE, Vol. 7093, 709302, (2008).

**KEYWORDS:** NMBS, LIDAR, LADAR, Non-mechanical, Steering, Beam Steering, Optical, conformal, sub-aperture, metasurfaces

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AF192-024            TITLE: Cognitive Fully Autonomous Sensor Technology (CFAST)

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop next generation cognitive and fully autonomous sensor technologies amenable to a highly distributed airborne swarm

DESCRIPTION: The global proliferation of advanced integrated defense system technologies continues to present a major challenge. It is recognized across the DoD that a distributed swarm platform architecture is needed. Major advances in commercial technologies i.e. embedded computing with integrated neuromorphic engine, software defined radios, and radar system on a chip, there is a major challenge in putting all this together. The goal of this research is to develop CFAST amenable technologies. Emphasis is on solutions that are low size, weight, power and cost. All physical sensor modalities will be considered. The focus of this research is the sensor payload, packaging, and platform integration, not on communications or networking.

PHASE I: Develop a fully integrated conceptual design for CFAST technologies. A basic feasibility analysis using modeling and simulation to establish a new sensor approach.

PHASE II: Further refine and prototype the CFAST design. The output should be a design that is ready to enter into a Phase III

PHASE III DUAL USE APPLICATIONS: DUAL USE APPLICATION: The proposer will identify potential commercial and dual use applications such as low SWAP-C sensors and embedded computing that include cognition engines.

REFERENCES:

1. L. O. Spencer, "US Air Force Key to Third Offset Strategy," in Defense News, ed, 2016.
2. Airborne Swarms. Available: <https://www.darpa.mil/news-events/2017-04-23>
3. Small form factor embedded computing. Available: <https://en.wikichip.org/wiki/apple/ax/a11>
4. R. Guerci and E. J. Baranoski, "Knowledge-aided adaptive radar at DARPA: an overview," Signal Processing Magazine, IEEE, vol. 23, pp. 41-50, 2006.

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AF192-025            TITLE: Fully Adaptive Radar Resource Allocation

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

OBJECTIVE: Develop techniques for radar resource allocation for closed-loop radar detection and tracking

DESCRIPTION: Onerous challenges imposed by an A2AD environment call for closed loop radar operation for concurrent detection and tracking of targets from single and distributed radar systems. In the context of the sense-learn-adapt framework or perception-action framework, this necessitates the use of past data to determine future radar illumination and data collection. Current techniques do not optimally and automatically balance the need to

detect, track, and identify targets. Recently, cognitive radar approaches have been used to compute sensing actions that are expected to maximize the utility of the received data. Similarly, past efforts on information-theoretic sensor management have produced a framework for managing the resources of an agile sensor, where the utility of the sensing action is judged by the expected amount of information flow.

This effort solicits the development of intelligent sensor management approaches for optimized sensing in a dynamic, complicated environment characterized as containing many moving targets, performing maneuvers that are intermittently obscured to the sensor. While previous efforts have focused on portions of this problem, this topic seeks approaches that address using multiple sensors for detection, and tracking of multiple targets from single and distributed radar in a closed loop manner. Specifically, we seek approaches to capture the scene probabilistically and use this information to drive future sensing actions, and lead to quantitative improvements in performance over current approaches as measured by standard tracking benchmarks such as time until correct detection and identification, track mean square error, and optimal sub-pattern assignment (OSPA). Ideally, we seek radar resource allocation techniques that incur a weak dependence on the number of sensors and the number of targets. The approach must afford application of ideas from cognitive sensing to guide agile sensor action at the next time step and beyond, such as selection of pointing, mode, waveform and PRF.

PHASE I: Develop a closed loop sensor management framework for concurrent detection, and tracking of ground targets in a single sensor setting. A host of multi-objective optimization problems encountered in this context, need to be addressed. Performance analysis and benchmarking of the approach are called for using standard measures.

PHASE II: Extend the approach to include distributed radars tracking multiple targets. Validation of the concepts need to be done via simulation and experimentation.

PHASE III DUAL USE APPLICATIONS: Techniques from this effort will be fundamental to the performance evaluation and benchmarking of closed loop radar detection and tracking. Technology insertion opportunities include platforms such as AWACS and Global Hawk.

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1. S. Haykin, Y. Xue, and P. Setoodeh, "Cognitive Radar: Step Toward Bridging the Gap Between Neuroscience and Engineering", The Proceedings of the IEEE, vol. 100, no. 11, pp. 3102-3130, Nov. 2012.
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KEYWORDS: Closed loop radar, Resource allocation, Distributed radar

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AF192-026 TITLE: Advanced Hyperspectral Exploitation Using 3D Spatial Information

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: N/A

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

**OBJECTIVE:** Develop advanced hyperspectral exploitation algorithms incorporating 3D spatial information for improved target detection and identification.

**DESCRIPTION:** Hyperspectral imaging (HSI) has demonstrated utility for material classification and target detection/identification. Generally, hyperspectral exploitation algorithms operate using spectral information alone due to insufficient spatial resolution of the sensor or the lack of coincident data from another sensing modality, such as RADAR, LIDAR, or passive 3D imaging. False alarms and low detection/ID confidence can exist for certain target classes that are not well separated using spectral information alone. As sensor technology matures, more opportunities exist to collect HSI data with coincident 3D spatial information at each pixel of the HSI data cube. This information could come from LIDAR data collected over the same spatial area or with novel passive sensing modalities, such as passive 3D HSI [1]. This additional information can be used to help improve the separability of material and target classes, thereby reducing false alarms and improving ID confidence.

Previous efforts in exploiting HSI with coincident LIDAR data have demonstrated benefits for material classification [2]. This effort seeks to improve and expand upon previous work with emphasis specifically on target detection and identification rather than material classification. Research should focus not only on the use of 3D spatial target information but implications for atmospheric characterization, shadow mitigation, bi-directional reflectance distribution function (BRDF) properties, and other items associated with the physics of radiative transfer.

Assumptions that can be made regarding this effort include: 1) sensor viewing geometry is known along with solar geometry, 2) targets will span multiple pixels, 3) a spectral library of target and background signatures exists, 4) knowledge exists about the 3D structure of the targets of interest in the sense that the target shape is known (i.e. vehicle shape/size, etc.), 5) hyperspectral data will be in calibrated spectral radiance units, and 6) 3D spatial information available for each hyperspectral pixel with in the form of point cloud data and/or co-registered digital surface model data at roughly  $\frac{1}{2}$  the ground sample distance of the HSI data.

Algorithms should produce a confidence measure associated with each target ID. Algorithms should demonstrate an order of magnitude decrease in false alarms with a 25% increase in ID confidence when compared with state-of-the-art spectral-only algorithms currently being used by the Air Force. Algorithms should be able to operate near real-time (within seconds or minutes of data collection) or a path demonstrated to optimize for near real-time operation using state-of-the-art processing hardware, such as graphical processing units (GPUs).

**PHASE I:** It will explore and develop novel algorithms and test with synthetic data if appropriate. Testing will continue using government furnished airborne hyperspectral data and coupled 3D point-cloud data. Algorithm performance will be quantified and compared with current state-of-the-art spectral-only detection and ID algorithms.

**PHASE II:** It will modify and further develop the algorithms based upon Phase 1 results. Further testing will occur using additional government-furnished data sets. The code will additionally be optimized with a hardware architecture identified for real-time or near real-time implementation.

**PHASE III DUAL USE APPLICATIONS:** It will transition the software for incorporation into existing hyperspectral exploitation tools or other assets based upon interaction with the customer.

**REFERENCES:**

1. J. Ahlberg, et al, "Three-dimensional hyperspectral imaging technique," Proc. SPIE, 10198, 1019805-1 – 1019805-10, (2017)

2. M. Khodadadzadeh, et al, "Fusion of Hyperspectral and LiDAR Remote Sensing Data Using Multiple Feature Learning," IEEE JSTARS, Vol. 8, No. 6, (2015)

**KEYWORDS:** target detection, identification, hyperspectral imaging, 3D fusion

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AF192-027            TITLE: Compact Broadband Thermal Imaging and LWIR HSI Payload for Small Unmanned Aircraft System (SUAS)

**TECHNOLOGY AREA(S):** Sensors

**ACQUISITION PROGRAM:** N/A

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

**OBJECTIVE:** Develop compact payload capable of collecting high spatial resolution thermal imagery and wide area longwave infrared (LWIR) hyperspectral imagery (HSI) to fit within the constraints of a 5" gimbal for use with SUAS platforms.

**DESCRIPTION:** The Air Force has a need to perform ISR in contested environments. Group I and II SUAS (i.e., those under 55 lbs) are potential enablers for such missions due to their low cost and low probability of detection. However, they lack sensors for nighttime, automated passive detection/ID over large areas, particularly for difficult targets like those hidden by camouflage, concealment, or deception. ISR using longwave infrared (LWIR) hyperspectral imaging (HSI) systems has demonstrated utility in those challenging scenarios, but existing systems are too large and do not meet the size, weight, power (SWaP) constraints imposed by SUAS. This topic seeks development of uncooled LWIR HSI systems or development of novel compact cooled systems to be integrated with a broadband thermal imaging system (either MWIR or LWIR) to fit within the SWaP constraints of a 5" gimbal and corresponding SUAS. This effort will provide a 5" diameter gimbal suitable for a Common Launch Tube-deployed SUAS of less than 50lbs operating at a typical slant range of 1500ft and altitude of 200 feet and higher. The gimbal shall provide broadband NIIRS-6-quality (T) (NIIRS-7 or better (O)) thermal infrared (TIR) imagery (either MWIR or LWIR) with LWIR hyperspectral measurements collected across a broader field-of-view (FOV) with nominally 1.5m (T) ground sample distance (GSD, 1.0m (O)). The LWIR HSI system shall cover a spectral range of 7.5-11um (T) (7.5-13.5um (O)) with adequate spectral resolution, quantified as the full-width half-max (FWHM) of the system spectral response function (SRF), and sensitivity, quantified as noise-equivalent spectral radiance (NESR), to detect a range of military targets for which signatures will be provided. Note, due to the SWaP constraints, solutions may require novel uncooled LWIR systems [2] or scanned point spectrometers using cooled linear detector arrays. The system shall provide on-board processing resources (FPGA, GPU) for integration of gov't provided algorithms for tracking and/or hyperspectral target detection/ID (T). The gimbal broadband TIR imagery shall be visually lossless after transmission (T). The transmitted chip/frame rate shall be 0.25 hertz (T), 2 hertz (O). Ground coverage of the TIR imagery shall be sufficient to fully encompass the rear aspect of a vehicle, 10x10 feet (T) (20 x 20 feet (O)) at

range. The LWIR HSI shall meet an area coverage rate of 5000m<sup>2</sup>/s (T) (20,000 m<sup>2</sup>/s (O)). The FOVs shall be operator-steerable over a large part of a lower hemisphere field of regard (T). This effort will not develop entirely new gimbal structures, but will develop a payload, and processing capability. An off-the-shelf gimbal or mature prototype is the expected starting point. This gimbal shall support typical SUAS maneuvering and fly-ins, and shall compensate for disturbances due to gusts and air turbulence. The gimbal should provide accurate line-of-sight pointing data, on-gimbal inertial measurement, and interface to platform GPS (T).

**PHASE I:** Identify the hardware requirements for a NIIRS-6-capable 5” TIR gimbal with spectrometer covering the LWIR portion of the spectrum, including stabilization, optics, and focal plane array. Conduct a Systems Requirement Review (SRR). Prepare a preliminary design of the gimbal and payload and hold a preliminary design review (PDR). Use modeling and simulation to justify performance.

**PHASE II:** Perform detailed design of the gimbal and payload. Conduct Critical Design Review. Continue modeling and simulation to improve system performance. Based on these results, build a prototype 5” gimbal and payload or breadboard system if budget does not permit full gimbal integration. Evaluate system performance in laboratory and tower (T), and flight test (O) environments. It shall not be assumed that the government will furnish the gimbal for payload integration. However, government facilities and equipment may be used in support of lab and/or tower testing.

**PHASE III DUAL USE APPLICATIONS:** Refine design based on outcomes of tests and customer feedback in Phase II; develop a manufacturing plan and/or select a partner for production of 5” gimbals.

#### REFERENCES:

1. Air Force Unmanned Aerial System (UAS) Flight Plan 2009-2047, <http://archive.defense.gov/DODCMSShare/briefingslide/339/090723-D-6570C-001.pdf>
2. P. Lucey, et al, “A compact Fourier transform imaging spectrometer employing a variable gap Fabry-Perot interferometer,” Proc. SPIE, 9101, (2014)

**KEYWORDS:** SUAS; Imaging; NIIRS, hyperspectral, thermal, longwave; gimbal

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AF192-028            **TITLE:** EO/IR-Specific State of the Art Machine Learning

**TECHNOLOGY AREA(S):** Sensors

**ACQUISITION PROGRAM:** N/A

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

**OBJECTIVE:** Develop EO/IR-specific state of the art machine learning method(s) for improving utility of ISR sensor products to provide enhanced interpretability and extend range performance over visual image assessments.



**DESCRIPTION:** The Sensors Directorate of the Air Force Research Laboratory (AFRL/RV) and AF Life Cycle Management Center have been partnering on sensor technology research and development for ISR applications covering a range of passive and active EO/IR sensor concepts. Relevant research has the potential to support the DoD in manned and unmanned airframes. For this topic, the research should focus on the capability of performing National Image Interpretability Rating Scale (NIIRS) 5 or better level tasks on NIIRS 4 imagery where the images acquired are degraded due to low signal to noise ratio, atmospheric conditions, etc. These tasks are to be performed on passive single band imagery. The rapid expansion of research in the areas of state of the art machine learning, artificial intelligence, and deep learning open the possibility of improved image interpretability at a given imaging range, as well as the potential for further extending range performance of EO/IR sensor systems. One major challenge is acquiring or accurately modeling datasets for training and learning. Acquired datasets would have to be labeled after the collection to aid with training and learning. Collection of training and learning data will be provided by the offeror, no government facilities, equipment, etc. will be provided. An additional, but related, challenge is that training data may only be collected over a pristine or limited set of conditions. It is important to understand how training datasets and machine learning transfers to other data collection ranges, environmental conditions, and even target variations. This area of research is known as transfer learning. Performance metrics will focus on accomplishing NIIRS 5 or better tasks on NIIRS 4 imagery with 75% accuracy as a threshold and 100% accuracy as an objective.

**PHASE I:** Research will focus on: 1) identifying and securing suitable datasets and/or modeling tools for providing data to train state of the art machine learning methods; 2) baselining a set of machine learning tools, including those methods required for feature extraction (including deep learning approaches), & transfer learning; and 3) providing an initial performance assessment, recommending next steps in refining state of the art machine learning tools.

**PHASE II:** Research will focus on refining machine learning tools based upon Phase I recommendations. Additionally, the contractor will secure, generate, or collect more relevant training data. The contractor will perform a final assessment of the machine learning tools, including assessing potential performance gains over visual image analyses and testing limitations of transfer learning methods. The contractor will deliver all developed tools, algorithms, and data to the government. The contractor will initiate discussions with sensor system developers, exploitation processing developers, and other avenues for transition of machine learning techniques.

**PHASE III DUAL USE APPLICATIONS:** This phase will match the Phase II machine learning tools with appropriate applications and pursue systems developers to refine and transition the tools for the specific system(s). The primary candidates include both existing operational and planned future DoD reconnaissance imaging systems, as well as commercial remote sensing systems for civil applications, such as mining and crop/forest health. The focus will be on refining tools that can be applied to detect, recognize, identify, and recommend actions in remote sensing performed by EO/IR sensors.

#### REFERENCES:

1. Zhang, Liangpei, Lefei Zhang, and Bo Du. "Deep learning for remote sensing data: A technical tutorial on the state of the art." *IEEE Geoscience and Remote Sensing Magazine* 4.2 (2016): 22-40.
2. Paxman, R. G., Rogne, T. J., Sickmiller, B. A., LeMaster, D. A., Miller, J. J., & Vollweiler, C. G. (2016). Spatial stabilization of deep-turbulence-induced anisoplanatic blur. *Optics express*, 24(25), 29109-29125.
3. Ball, J. E., Anderson, D. T., & Chan, C. S. (2017). Comprehensive survey of deep learning in remote sensing: theories, tools, and challenges for the community. *Journal of Applied Remote Sensing*, 11(4), 042609.
4. Marcum, R. A., Davis, C. H., Scott, G. J., & Nivin, T. W. (2017). Rapid broad area search and detection of Chinese surface-to-air missile sites using deep convolutional neural networks. *Journal of Applied Remote Sensing*, 11(4), 042614.

**KEYWORDS:** remote sensing; high-resolution imaging; multispectral; hyperspectral; deep learning; convolutional neural networks; object detection; target recognition; imaging through turbulent media; Image reconstruction-restoration; hyperspectral; big data; computer

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AF192-029 TITLE: High-Resolution Rapid Refresh (HRRR) Weather Nowcasts

TECHNOLOGY AREA(S): Information Systems

ACQUISITION PROGRAM: N/A

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

**OBJECTIVE:** Develop high-resolution rapid refresh weather forecasts (Nowcasts) in support of real-time battle management (RPA, dynamic taskings, etc.) in data-sparse locations.

**DESCRIPTION:** There have been a number of breakthroughs in the public and private sector utilizing traditional data sources to gather weather data to develop a short-term rapid update weather model. The Air Force has a large number of non-traditional data sources that could be used to gather and feed a large swath of previously unavailable weather data into the AFW Enterprise and forecasting systems. These unique AF & DoD non-traditional data sources, such as OPIR (Overhead Persistent Infrared), should be explored for use in local data assimilation to improve model performance for support of high-resolution rapid-refresh-like "Nowcast" capabilities. This would aid in weather support to time-sensitive operations in limited domains, such as remotely piloted aircraft and Chemical, Biological, Radiological and Nuclear (CBRN) events occurring in down-range operations.

**PHASE I:** Conduct an analysis to identify any likely non-traditional data sources (available and near-term), such as OPIR, within the AF/DoD from which weather data could be gathered but has not been, historically.

**PHASE II:** Based upon the research in Phase I, develop an algorithm or data analysis technique to extract environmental information from the non-traditional data sources and integrate it with AFW model data into a Nowcast system.

**PHASE III DUAL USE APPLICATIONS:** Expanding upon work from Phase II, identify and develop means to integrate and present Nowcast information to users through the AFW Enterprise system. Identify and address any gaps between the proposed solution and the AF requirements.

**REFERENCES:**

1. Air Force Weather Operations Roadmap (November 2017), HQ USAF/A3W, Washington, DC
2. Rapid Refresh (RAP) NOAA Hourly Assimilation/Modeling System at Earth System Research Laboratory: <https://rapidrefresh.noaa.gov/>
3. Sun et al, 2014: Use of NWP for nowcasting convective precipitation. Bull. Am Met. Soc., 2014, 409-426. <https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-11-00263.1>
4. Browning, K.A., 1982: Nowcasting. Academic Press, London, 256 pp.

**KEYWORDS:** weather forecasting technology, nowcasting, high resolution numerical weather prediction, OPIR, 4 dimensional data assimilation, rapid update cycles

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AF192-030            TITLE: Next Generation Miniature Charged Particle and Multi-Phenomenology Detectors

**TECHNOLOGY AREA(S):** Space Platforms

**ACQUISITION PROGRAM:** Pervasive

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

**OBJECTIVE:** Develop detector technology that can drive Energetic Charged Particle sensor SWaP below current State of the Art by 6x or more while simplifying design and adding multi-phenomenology detection capability.

**DESCRIPTION:** While current Energetic Charged Particle (ECP) sensors are acceptable for large space systems (~4kg, 10W, 3600cc) [1] and a second generation is being developed with 2x to 4x reduction in SwAP, further reduction in SWaP and system cost and complexity while retaining the full sensor capability [2] is desired for future systems using a variety of dedicated, contributing, and hosted platforms, ranging in size from current large vehicles to cubesats. As even second generation ECP sensors are large compared to some of these platforms, further reduction in SWaP is desired, but the minimum sensing capability remains a requirement.

The intent is to develop detector technology that can be shown to drive down not just detector SWaP, but overall system SWaP by a factor of 6x or more over existing designs while adding phenomenology detected by reducing detector size, simplifying the electronics required to acquire the data, and limiting the need for high voltage, low-noise electronics, on-board data processing, etc. While [2] lists the energy range desired, some relief may be granted on energy range if dramatic SWaP reductions can be demonstrated while otherwise meeting requirements. As an example, utilizing solid-state detectors to avoid the need for higher-SWaP approaches to spectroscopy for energies below 1keV is an attractive option, even if it is unlikely to achieve the absolute lowest energy range required. The design should be able to be shown to function within the extreme space environment that is desired to be measured and not be susceptible to contamination from photons, other particle species, or different energies of the desired particle measurement.

Additionally, detection of phenomena beyond energetic particles is desirable to support broader space situational awareness (SSA) needs, including other natural and man-made effects [i.e. 3]. Addition of detected phenomenology could lead to improved awareness for the host vehicle, and reduce the overall system SWaP. Additional capability to discriminate other threat and hazard phenomenology is strongly desired, but the detector must be able to properly characterize both the ECP environment and the additional phenomenology as hazardous or benign simultaneously, within desired accuracies.

**PHASE I:** Evaluate proposed detector technology via modeling and simulation, limited prototyping, and conceptual design studies to evaluate suitability for ECP and other detection missions while achieving SWaP reductions.

PHASE II: Refine detector technology. Develop and test breadboard detector/sensor mockup to show SWaP gains and test detector against laboratory representations of the charged particle environment and other phenomenologies.

PHASE III DUAL USE APPLICATIONS: Develop demonstration sensor system suitable for insertion into ECP sensors and/or other detector technologies. Support demonstration of multi-phenomenology detection on test flight or in assorted high-fidelity laboratory environments. If suitably capable, this technology should find broad uptake throughout national security space and potentially for commercial and civil customers as well.

#### REFERENCES:

1. Lindstrom, C “The Compact Environmental Anomaly Sensor Risk Reduction (CEASE-RR): A Pathfinder for Operational Energetic Charged Particle Sensors” IEEE Nuclear and Space Radiation Effects Conference, 17-21 July 2017, New Orleans, LA
2. Wheelock, A. “White Paper on ECP Energy Range and Flux Requirements” [[WILL PROVIDE AS ATTACHMENT TO SITIS ENTRY]]
3. Stephani, K. A., et al. (2014), Analysis and observation of spacecraft plume/ionosphere interactions during maneuvers of the space shuttle, J. Geophys. Res. Space Physics, 119, 7636–7648, doi:10.1002/2013JA019476.

KEYWORDS: spacecraft, anomaly, attribution, energetic charged particle, threat warning

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AF192-031 TITLE: Non-destructive Imagery and Analysis Techniques for Identification of Deleterious Defects in Li-ion Batteries

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

OBJECTIVE: Develop non-destructive evaluation techniques to image and analyze defects and non-uniformities in Li-ion batteries, and correlate those to a failure mechanism of the cell.

DESCRIPTION: Undetected defects and non-uniformities in Li-ion cells can impact a spacecraft’s mission assurance, causing costly integration and launch delays or even catastrophic mission failure. These defects can originate from the manufacturing process or form during cycling or transportation. Non-destructive evaluation and analysis of Li-ion cells can prevent defective or degraded cells from impacting mission assurance. Common non-destructive evaluation techniques for internal imaging of Li-ion cells and batteries are computed tomography (CT) X-ray imaging, magnetic resonance imaging (MRI), and thermography. Poor contrast, excessive image noise, low spatial resolution, and artifacts contribute to poor image quality with these techniques, and can prohibit proper flaw identification and resolution of fine features. Beyond defect identification, analysis of defect type and impact on performance is also critical for mission assurance. This solicitation aims to improve non-destructive evaluation and analysis techniques for enhanced understanding of internal defects and their correlation to cell failure mode.

Examples of defects include foreign object debris, non-uniformities, and other manufacturing defects, such as wrinkles or tears within an electrode stack or jellyroll, and within free space in the Li-ion cell. Some examples of defects formed during cycling and transportation are dendrite growth and gas pocket formation. These undesirable Li-ion cell flaws can result in increased self-discharge, internal shorts, and degraded cell performance.

Methods proposed under this solicitation must demonstrate detection, identification, and analysis of undesirable manufacturing defects and hazardous cell evolutions. Non-destructive techniques and methods with spatial resolution comparable with the onset of dendritic growth are of interest. Techniques should present a method to

differentiate features of interest from artifacts. Analysis should consider defect type, size, and effect on cell performance, to include failure mode. Analysis techniques can be software related or other. Techniques should be non-intrusive and provide timely data without impact to manufacturing operations. Research techniques that would be prohibitive or inappropriate in a manufacturing environment are not the focus of this solicitation. Advancements to non-destructive techniques and analysis mentioned above and novel techniques not described in this solicitation will be considered.

PHASE I: Perform preliminary analysis of NDE technique in a laboratory setting. Determine critical defect size, resolution, and limitations of imaging technique. Correlate defect type to cell failure mode.

PHASE II: Demonstrate NDE technique in a manufacturing setting. Relate defect type, size, and location to degradation or failure mechanism of cell with accompanying software and/or database. Demonstrate high-throughput process with minimal effect on manufacturing time and process.

PHASE III DUAL USE APPLICATIONS: Validation testing of proposed non-destructive technique and analysis with minimal impact to operations in a manufacturing setting.

#### REFERENCES:

1. D.P. Finegan, et al., Investigating lithium-ion battery materials during overcharge-induced thermal runaway: an operando and multi-scale X-ray CT study, Physical Chemistry Chemical Physics, Royal Society of Chemistry 18, 30912-30919 (2016).
2. Shearing, P.R., et al., Multi Length Scale Microstructural Investigations of a Commercially Available Li-ion Battery Electrode, J. Electrochem. Soc 159, A1023-A1027 (2012).
3. Romanenko, K., et al., New opportunities for quantitative and time efficient 3D MRI of liquid and solid electrochemical cell components: Sectoral Fast Spin Echo and SPRITE, J. Magnetic Resonance 248, 96-104 (2014).
4. Robinson, J.B., et al., Detection of Internal Defects in Lithium-ion Batteries Using Lock In Thermography, ECS Electrochem. Lett. 4, A106-A109 (2015).

KEYWORDS: Non-destructive evaluation, Li-ion, defects, mission assurance

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AF192-032 TITLE: Novel Sensor Solutions for Qualification of Additively Manufactured Launch and Space Vehicle Components

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: EELV - Evolved Expendable Launch Vehicle

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

**OBJECTIVE:** Develop sensor solutions that can be embedded into printed structures and aid in the qualification of Additive Manufacturing (AM) components for launch and space vehicles.

**DESCRIPTION:** The world of manufacturing is changing rapidly, with products being designed, made, and used in new ways as a result of AM. Processes used to manufacture critical components for launch and space vehicle component applications must still be formally qualified. While efforts are underway to tackle the process, alternative methods call for embedded sensors to be integrated into parts during the printing process. These sensors are envisioned to be utilized for qualifying the part during and after production, but may also be useful after production for assessing component integrity during fielded use. Various sensing methodologies are of interest including but not limited to purely passive components such as strain gauges, thermistors, etc. as well as active solutions that utilize powered components to generate elastic waves or characterize structural responses like piezo-electrics. Sensors can be read via wired approaches by taking leads to test points on the external surface of the part, however, more advanced methods are of interest that incorporate wireless methods for data and power as well as suit materials that are metallic or dielectric. Furthermore, it is ideal if the sensor can be printed along with the part rather than be a separate component that is embedded requiring process halting for manual labor, but this is not a requirement. While no one technology is expected that an address all stated needs, this list is intended to define the scope of interest.

**PHASE I:** Develop sensing method and evaluate effectiveness for characterizing print relevant defects and assess integration/embedding methodologies and impact of insertion on overall print quality. Demonstrate by analysis and/or test the feasibility of such concepts and that the approach be utilized for qualification of a representative part.

**PHASE II:** Demonstrate the technology developed in Phase I. Tasks shall include, but are not limited to, a demonstration of embedded functionality, limitations of approach in a larger setup.

**PHASE III DUAL USE APPLICATIONS:** Utilize the process developed during phase II and implement the approach on prototype launch vehicle or spacecraft hardware. Develop an approach and means to transition the technology to the user community including industry, academia, and government.

**REFERENCES:**

1. Macdonald, et.al., Multiprocess 3D printing for increasing component functionality, Science , Vol. 353, Issue 6307 , 30 Sep 2016.
2. Seifi, et al., "Overview of Materials Qualification Needs for Metal Additive Manufacturing," Journal of Materials, March 2016, Volume 68, Issue 3, pp 747-764
3. "A Summary Review of Wireless Sensors and Sensor Networks for Structural Health Monitoring," The Shock and Vibration Digest 2006.
4. EELV New Entrant Certification Manufacturing and Quality audits, SpaceX, 2014-15

**KEYWORDS:** Additive Manufacturing, 3d printing, qualification, sensors, wireless, inspection, verification, validation, launch vehicle, space vehicle, satellite

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AF192-033 TITLE: Next Generation Device Attachment Thermal Interface Material

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: --

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

**OBJECTIVE:** Develop a high-conductance, device attach thermal interface material (TIM) for use in high power density applications such as the interface between a GaN Power Amplifier and heat spreader or carrier.

**DESCRIPTION:** Current thermal management of solid state power amplifiers (SSPAs) in space is limited in its ability to spread power densities from the channels of active Power Amplifier devices (PA) to the large area thermal radiators required for ultimate rejection of heat to space. Current power densities at the bottom of the PA device can exceed 62 W/cm<sup>2</sup> and are expected to climb to values >1488 W/cm<sup>2</sup> in the next 5-6 years. At these expected power densities, it is apparent that current state of the art solders used at this interface will no longer be acceptable due to the need for higher performance.

The Device Attachment TIM shall provide a heat transfer coefficient >1340 W/cm<sup>2</sup>-C over an area of 0.3 cm x 0.3 cm. The TIM shall provide sufficient attachment with high thermal performance to survive various environments it will be subjected to through the satellite mission, including dynamic loads, large diurnal variations, and thermal cycles. The high thermal conductance is required in a space environment (vacuum and no gravity), as well as on Earth in any orientation with respect to gravity for ground testability. The TIM shall meet performance over an operating temperature range of 0°C to 150°C and must survive a temperature range of -60°C to 150°C. Please be sure to address the thermal induced stress on the heat spreader after thermal cycles in a specific application as this will vary depending on the mission. In addition, the TIM shall not require significant cure time or any harsh processing environments that would damage the device, unit or system (including temperatures over 250 °C). The TIM shall be free of potential workmanship issues to avoid (or at least limit) the thermal vacuum testing required for recurring, standard designs.

Proposers are highly encouraged to team with systems integrators and payload providers to ensure applicability of their efforts and to provide a clear transition path.

**PHASE I:** Develop concepts to provide a robust, reliable TIM that has the potential to provide a heat transfer coefficient >1340 W/cm<sup>2</sup>-C. Demonstrate by analysis and/or test the feasibility of such concepts to meet all requirements stated above.

**PHASE II:** Optimize and fully demonstrate a TIM capable of providing an effective heat transfer coefficient >1340 W/cm<sup>2</sup>-C. Perform thermal performance testing and thermal cycling to confirm all above requirements have been met under both on-orbit and ground test environments to verify susceptibility of debonds at large temperature variations and power densities. Perform testing on a large number of samples to verify robustness and that the TIM is independent of workmanship issues.

**PHASE III DUAL USE APPLICATIONS:** This research would benefit all military and commercial satellite programs, including MILSATCOM and global positioning satellite programs. TIMs are required for all high power electronic components used on aerospace systems.

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4. "Spacecraft Thermal Control Workshop Proceedings," Aerospace Corporation, March 20-22, 2018 (available directly from Aerospace Corporation at stcw.mailbox@aero.org)

KEYWORDS: 1. Thermal Management  
2. GaN Power Amplifier  
3. Thermal Interface  
4. High Power  
5. Solder  
6. Die Attach

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AF192-034 TITLE: Laboratory Benchtop Accelerator for Charged Particle Detector Calibration

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: ECP for WSF, NG-OPIR, others

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

OBJECTIVE: Develop a laboratory benchtop-sized charged particle accelerator suitable for supporting calibrations and characterizations of Energetic Charged Particle (ECP) sensors without resorting to licensed radioactive sources and/or large accelerator facilities.

DESCRIPTION: The Air Force has mandated Energetic Charged Particle (ECP) sensors on all future Air Force satellites. In order for these sensors to accurately measure the space environment, calibration is usually required. For charged particle detector calibrations, the current norm is to use a limited number of accelerator facilities that are large, expensive, and heavily subscribed. Additionally, many facilities are sufficiently old that they may have unexpected down time for maintenance. In addition, the facilities are largely optimized for either medical or radiation effects testing. The typical alternative is to use licensed radioactive sources, which can emit particles at high enough energies to simulate the space environment. However, these radioactive sources emit a spectrum of energies, making true calibration challenging. In addition, radioisotopes that emit high energy protons do not exist. A benchtop- or rackmount-sized, spectrally pure charged particle accelerator as a calibration source would allow for ECP vendors to perform their own calibrations of sensors without licensed radioactive sources and the need for expensive and hard-to-schedule beam time at larger accelerator facilities.

The objective of this topic is to develop a laboratory benchtop calibration source that can provide a narrow, spectrally-pure, beam for calibration of ECP sensors. These sources would accelerate electrons from 10 (far term goal) to 50 (near term goal) keV at the lowest energies up to 2 (near term goal) to 5 (far term goal) MeV at the highest energies and/or protons (highly desired) from 1 MeV up to 10 (near term goal) to 100 (far term goal) MeV with a beam energy full width half max of less than 25% (near term goal) or 10% (far term goal). It is desired that



the accelerator can be tuned over a range of energies up to its maximum. Unlike much of the current focus in tabletop accelerator research, the desired particle flux needs to be relatively low and ideally adjustable: 1 particle/cm<sup>2</sup>/s to 10<sup>6</sup> particles/cm<sup>2</sup>/s. It is desired that this low particle flux is ideally retained throughout the entire accelerator so that radiation protection requirements can be kept to a minimum. Methods of limiting the maximum produced particle flux are also highly desired to prevent damage to equipment under test as well as reducing radiation protection requirements. The particle flux produced needs to be as close as possible to an unbunched, continuous source as most existing space particle sensors experience pile-up/dead-time when inter-particle arrival times at the sensor approach 1 μs. Finally, the source beam is desired to be as uniform as possible across at least a 1” beam spot.

(SSA TN 952)

**PHASE I:** Initial design and modeling of system performance. Perform risk-reduction prototyping of key components leading to demonstration of accelerator behavior.

**PHASE II:** Prototype bench accelerator capable of demonstrating all key technologies and identifying necessary additional technology improvements required to meet goals. Demonstrate beam energy tuning capability and document system operation.

**PHASE III DUAL USE APPLICATIONS:** Develop and document final product suitable for straightforward laboratory use and further commercialization.

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**KEYWORDS:** calibration, accelerator, charged particle, miniaturization

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AF192-035      TITLE: Develop Prototype Hyperspectral Microwave Imager for Terrestrial Weather

**TECHNOLOGY AREA(S):** Sensors

**ACQUISITION PROGRAM:** AFRL Space Environment Exploitation and Mitigation

**OBJECTIVE:** Development of a prototype hyperspectral microwave sensor which significantly increases the bandwidth and line channel spatial wavenumber density of space-based passively-measured microwave radiances emitted and transmitted through the earth's atmosphere. The anticipated products of the prototype hyperspectral microwave sensor include improved accuracy and diagnosis and prediction of 3-D radiative transfer through optically-thick clouds which can assist missile launch plume detection in the presence of sunlit-clouds.

**DESCRIPTION:** Modern passive microwave space-borne sensors have a limited number of channels available, totaling between 5 and 30 channels. This limited number of channels has been shown to be insufficient to solve for

the ill-posed nature of the inversion of the geophysical state from space-borne measurements. This is especially true for cases where cloud, rain and/or ice are present in the atmosphere. In this case, a large uncertainty exists due the lack of knowledge about the particle density, shape, size distribution, vertical structure, and temperature dependence. A larger number of channels will help solve for the inherent ambiguities in these cases. This will also provide (1) a higher vertical resolution for the temperature and humidity sounding in all-weather conditions, (2) a better distinction between the surface and the atmospheric signals leading to retrievals of ocean wind vectors, snow and ice, soil moisture, (3) better surface typing due to the different spectral signatures associated with the different surface parameters mixtures, and (4) a better characterization of the microwave spectroscopic parameters (line width, line strength, line shape, frequency shift). While sensors operating in the infrared, short wave infrared, and near-infrared have experienced an ever increasing number of channels and bands with the new hyperspectral sensors, microwave sensors -- despite their large proven benefits to numerical weather prediction and their ability to penetrate cloud and sense within and below the cloudy and rainy layers -- have not seen their number of channels increase, mainly due to technological challenges.

This type of sensor would be expected to have significant positive impacts on the forecast skills of numerical weather prediction models due to the increase in sounding retrievals, especially if deployed in space with large spatial and temporal coverages. This improvement is expected in medium-range weather forecasts as well as in the nowcasting/short-term forecasting of mesoscale events. Besides the large number of channels (between hundreds and thousands) sought, in a range between 6 GHz and 300 GHz, it is emphasized that the noise level should be as low as possible and at least as low as current state of the art sensors by taking advantage of the new developments in radiometry technology.

**PHASE I:** Define what is meant by "hyperspectral microwave" in terms of frequency, wavenumber, and wavelength differentials, including the total number of channels. Develop a prototype hyperspectral microwave sensor design to include expected signal-to-noise ratio, radiance levels, channel or band spatial wave-number spacing, and applicable observing system simulation experiments (OSSE) in order to assess the impact of additional spectral channels and bandwidth on numerical weather prediction accuracy.

**PHASE II:** Build a prototype hyperspectral microwave sensor based on the design approved in phase I employing the most recent technological advances as appropriate. Conduct phased sensor tests including on-ground, tower borne, and airborne tests. Refine data assimilation techniques for ingestion of the hyperspectral measurements into 3-D cloud forecast models such as those developed at the 557th Weather Wing.

**PHASE III DUAL USE APPLICATIONS:** Apply the space-based hyperspectral microwave sensor towards military applications including 3-D global cloud diagnoses and forecasts, and surface snow and ice cover for ISR and Missile Warning. Civilian applications potentially include improved aviation weather hazard and in-flight forecasts and medium range weather prediction.

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2. Townes, C.H., and A.L. Schawlow, 1975: *Microwave Spectroscopy*. Dover, New York, 699 pp.
3. Rothman, L.S., et al, 2013: The HITRAN2012 molecular spectroscopic database. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 130, 4-50.
4. Liu, Q., and F. Weng, 2002: A microwave polarimetric two-stream radiative transfer model. *Journal of the Atmospheric Sciences*, 59, 2396-2402.

**KEYWORDS:** molecular spectroscopy, emissivity, polarization, radiative transfer, transmission, reflection, absorption, microwave imagery, microwave soundings, weighting functions.

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AF192-036

TITLE: Large Area Solar Simulator for Next Generation Solar Panels

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

OBJECTIVE: Develop large-area, low-cost, solar simulator capable of AM0 illumination of solar modules composed of multijunction solar cells with more than three subcells.

DESCRIPTION: The 30% efficient InGaP/InGaAs/Ge triple junction solar cell has been considered state-of-practice among nearly all major government and commercial spacecraft for over a decade [1]. The U.S. Air Force (AF), in collaboration with the U.S. space solar cell industry, continues to drive improvements of multijunction solar cells to improve size, weight, and power (SWaP) metrics. Higher solar cell efficiency and novel array architectures provide mission enabling power levels and reduce system-level costs. To continue pushing the limits of SWaP metrics, new solar cell architectures are being developed, such as the inverted metamorphic multijunction (IMM) architecture [2]. Some of these designs contain more than three subcells and thus require new specialized characterization equipment. Accurate electrical characterization (e.g., current-voltage (I-V) measurements) of these new space solar cells require new tools such as multi-zone solar simulators that are capable of accurately simulating the AM0 spectrum and give the ability to tune the spectral intensity within certain spectral ranges [3]. In addition to testing at the cell level, panel-level integrators must use large-area solar simulators, such as a large-area pulsed solar simulator (LAPSS) [4], to characterize the output at the panel level. The measurements gained from using these tools give confidence in the electrical output at a high level of integration (i.e., including cells, interconnects, wiring, bypass/blocking diodes, etc.).

In recent years, cell development has outpaced development of large-area simulators capable of testing panels that incorporate new, >3 subcell multijunction cell architectures. The Air Force is seeking to develop a large-area pulsed solar simulator capable of AM0 illumination of a 2m X 2m space solar array panel that contains solar cells with >3 subcells. The simulator should be capable of 2% areal uniformity and 2% temporal stability, allow for adjustable intensity, and be spectrally tunable to accommodate different solar cell architectures. . The pulse length should allow for a full I-V sweep or for a data point(s) to be taken per pulse so long as the panel can be adequately thermally controlled. The simulator developed under this program should be capable of satisfying the illumination requirements of the AIAA-S112 qualification for space solar array panels.

Recently, LED based solar simulators have been used for characterizing CubeSat arrays [5] and show promise for large area applications. However, due to their relatively small illumination area, many LEDs must be used which adds complexity. These challenges may be overcome though with proper cooling and electrical integration and control. This call for proposals does not require a solution based on LEDs but would welcome potential ideas incorporating them.

PHASE I: Develop large area solar simulator designs that enables characterization of large area (2m X 2m) space solar array panels under the AM0 spectrum. Perform preliminary testing and analysis of the identified options to support down select and Phase II development planning.

PHASE II: Mature the most promising large area solar simulator design and perform required testing and analysis to determine the uniformity and stability of the electrical characterization at the panel level using the simulator as an illumination source. The goal is to have the technology matured to TRL 4 or higher at the end of the Phase II effort.

PHASE III DUAL USE APPLICATIONS: Deliver full-scale AM0 solar simulator capable of illuminating 2m X 2m solar module with 2% areal uniformity and 2% temporal stability. The simulator should be capable of satisfying

AIAA S-112 requirements.

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KEYWORDS: high-efficiency, solar cell, large area pulsed solar simulator, inverted metamorphic

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AF192-037 TITLE: Military GNSS Data Server

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

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

OBJECTIVE: Develop a Military GNSS Data Service that gathers GNSS ephemeris, clock, health, status, and other key information, ensures the trustworthiness of the data, and is capable of delivering data to military data networks.

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

Traditionally, military users have relied on access to the navigation data message from the GPS signal in space to obtain current ephemeris, clock, satellite health, and other important data necessary for Positioning, Navigation, and Timing (PNT) from GPS. Due to the slow data rate of the Navigation Data Message (NDM) and an average age of data of 12 hours, the resiliency and performance of military receivers is actually, in some cases, worse than consumer devices. Billions of cell phones with inexpensive GPS chip sets benefit from Assisted GPS (A-GPS),

which provides current ephemeris and timing data that enables rapid acquisition of the GPS signal and, in many cases, more accurate positioning and timing.

No joint military A-GPS capability exists today. Typical Time-to-First-Fix (TTFF) requirements for military receivers are specified in tens of seconds or minutes, compared to less than 6 seconds for a typical A-GPS equipped cell phone. A key technical challenge is developing open data standards and interfacing with diverse DoD networks while providing a high degree of trust and resilience against cyberattacks. Additionally, as military users migrate to multi-GNSS, there is a need to provide near real-time notification of anomalies to users over available datalinks.

The focus of this topic is developing a Military GNSS Data Service, drawing data from GPS and GNSS monitoring systems, suitable for integration with operational networks in an Area of Operations, that supports three enhancements to traditional satellite navigation. First, improved resiliency is obtained by assisted-GPS/GNSS data that improves initial synchronization performance. Second, enhanced accuracy is achieved by delivering Zero Age of Data (ZAOD) to the user, reducing the position and timing errors associated with satellite clock and ephemeris errors. Third, improved integrity is supported by providing users with near real-time notification of GPS or GNSS anomalies. Together, these capabilities provide a powerful enhancement to GPS and multi-GNSS use on the battlefield, leveraging existing tactical data links, and with little to no modification of military receivers.

The primary goal of this effort is to develop the data service, including the architecture, protocols, interfaces, and information assurance features necessary to deliver trusted GNSS data to military users. Consideration should be given to extracting data from multiple monitoring sources such as the GPS control segment, National Geospatial-Intelligence Agency, the Jet Propulsion Laboratory, and other government and commercial sources. New monitoring stations are not within the scope of this topic, although leveraging new or emerging monitoring receiver and monitoring station initiatives is encouraged.

The ultimate goal for a Military GNSS Data Service is a joint capability that services air, land, sea, space, and cyber domains. However, for this SBIR topic, demonstration of the capability for a single domain is acceptable, providing the solution is scalable to support diverse applications across all domains.

**PHASE I:** Develop an architecture and preliminary design for a Military GNSS Data Service to support a single domain, with a plan for demonstrating the capability for a targeted application in Phase II.

**PHASE II:** Implement and demonstrate a prototype Military GNSS Data Service for the targeted application, including GPS and Galileo data. The prototype should provide a real-time demonstration of the benefits of Military Assisted GNSS, including acquisition, accuracy, and integrity warning.

**PHASE III DUAL USE APPLICATIONS:** Develop a Joint Military GNSS Data Service that supports multiple domains, and can be integrated into a theater command and control system.

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**KEYWORDS:** GNSS Data Service, A-GPS, Alternate-GPS

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AF192-038

TITLE: Development of Graphene Batteries for Use in Space Applications

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

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

OBJECTIVE: Mature use of graphene in a Lithium-Ion Battery through the development of full cell configuration using pre-lithiated anodes.

DESCRIPTION: Mass of spacecraft power system components can be a significant portion of the overall spacecraft mass. In order to reduce the mass required for spacecraft batteries and to meet exponentially increasing satellite energy requirements to support tomorrow's warfighters, advanced energy storage cell development is required. Current Lithium-ion batteries use graphite as an anode. The use of graphene or graphene enhancements to replace graphite shows great promise in providing high gravimetric capacity while also maintaining reasonable cycling stability. Proposed technologies should be able to withstand 3-5 year operational lifetimes, maintain reasonable capacity (80%), and exhibit cycling stability after 20,000 cycles. Much research has been performed exploring graphene enhancements to energy storage cells. Review of the literature shows several different graphene and graphene enhanced anodes with 2x gravimetric potential compared to graphite and modest reduction in cycling capacity. Most research was performed in a half cell configuration which doesn't provide an accurate picture of energy and power density for operational cells. This topic aims to advance graphene electrodes and graphene enhancements to full cells for a space application. Approaches may include improvements to cell components, novel materials or processes, or other innovative ideas. However, production of full cells requires a pre-lithiation step to obtain decent electrochemical performances which increases difficulty in battery manufacturability. Producing a full cell, with a pre-lithiation step, is critical in assessing future graphene performance as an anode in battery use.

PHASE I: Utilize existing research to determine viability and suitability of graphene anodes for future development into a full cell configuration. Perform initial testing and analysis of available graphene enhancements and anodes with chosen cathode(s) to down-select. Predict performance metrics (energy/power density, etc.) for chosen anode/cathode/electrolyte combinations.

PHASE II: Of the downselected graphene or graphene enhanced anodes, perform a manufacturing study to determine which material types are optimal for prelithiation steps. Based on the results of the study, begin the process of creating a manufacturing method that simplifies the prelithiation stage and provides consistent prelithiation results. Execute the pre-lithiation stage and analyze the results.

PHASE III DUAL USE APPLICATIONS: Manufacture the prelithiated anodes. Determine anode/cathode/electrolyte formulations for best performance and combine into full cells. Characterize the full cells for energy, power density and weight for potential space qualification.

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2. Pre-Lithiation Strategies for Rechargeable Energy Storage Technologies: Concepts, Promises and Challenges <https://www.mdpi.com/2313-0105/4/1/4/htm>

3. Current Progress of Si/Graphene Nanocomposites for Lithium-Ion Batteries  
<https://www.mdpi.com/2311-5629/4/1/18/htm>

4. Characterization of a hybrid Li-ion anode system from pulsed laser deposited silicon on CVD-grown multilayer Graphene <https://link.springer.com/article/10.1007/s00339-014-8271-0>

KEYWORDS: graphene, anode, pre-lithiation, gravimetric

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AF192-039 TITLE: Plug-and-Play Technology for Distributed Modular Propulsion Engine Controls Design

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: F-22 - RAPTOR Advance Tactical Fighter

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

OBJECTIVE: To provide architectures that enable propulsion systems upgrade/change with minimal cost and effort. To design modular, and self-adapting architectures to link new and legacy propulsion systems.

DESCRIPTION: A propulsion system consists of a source of mechanical power, and a propulsor (means of converting this power into propulsive force). When it comes to integrated propulsion systems, there's a lot of work that goes into power plant and propulsor matching on a performance level, before control ever gets involved. Hence the idea of core and prop/fan modules as separate elements that could be swapped around with a plug-and-play (PnP) system would be an efficient technology. Adaptive and peak-seeking control tools integrated in a decentralized architecture could enable PnP development of entire families of propulsion systems. The research includes the software and hardware aspects of the PnP technology development for propulsion systems.

In the futuristic engine control vision, engine cores and props/fans could be purchased with their onboard subordinate controllers ready for integration into a functional propulsion system, whereas the FADEC was developed independently for the integrated engine. When it comes to integrated propulsion systems, there's a lot of work that goes into power plant and propulsor matching on a performance level, before control ever gets involved. Hence the idea of core and prop/fan modules as separate elements that could be swapped around with a plug and play system would be an efficient technology. Helicopters and other VTOL aircraft systems might be good candidates though, since in those cases one could consider the core power plant as a swappable module. A given helicopter with a given set of rotor blades could be made to work with various Original Engine Manufacturers (OEMs) Furthermore, the PnP technology can be implemented in automobile and marine propulsion systems. The design approach would eliminate control interfaces compatibility issues. Commercial manufacturers of gas turbine engines rarely design all new engine centerlines; the lifespan of successful engine families is decades. Many of the new engines designed in a family are based on an existing engine core, primarily due to cost and reliability concerns. The high-pressure compressor and turbine contain the highest performance, and therefore most expensive, components. Engine core designs may move from military turbojets into commercial turbo-fans and turbo-props.

A similar niche is occurring in UAV development, where small gas turbines are being used to power a variety of different lift/thrust devices. UAV development programs rarely have the resources for serious engine redevelopment and therefore must select from a limited number of commercial off the shelf (COTS) engines. In the case of small gas turbines these COTS engines are generally designed for missile turbojet or power generator applications, while the UAV designer may want to use the engine core in a turbo-prop or turbofan application. Successful development of decentralized adaptive control for this class of engines would allow UAV designers to purchase engines with onboard controllers and mate them with their own proprietary fan/prop sections without having to design a new control system from scratch.

For propulsion system PnP technology development, adaptive and peak-seeking control techniques can be used. Adaptive control, for fuel regulation, and a self-tuning controller, for prop/fan angle regulation, integrated in a decentralized control architecture is the general structure of this PnP technology.

Using this technology, the propulsion system fan/prop with its subordinate controller can be plugged in to the various propulsion system cores with their own subordinate controllers, which also include the supervisory controller, and vice versa. With the aid of this technique, different engine cores can be matched to different props/fans, and the whole propulsion system should work without any more performance tuning. For example, in geared turbofan engine systems, physical separation of core and propulsor provides an alternative to the geared fan architecture by enabling the integration of variable pitch fans in the geared turbofan engines using PnP technology.

The plug and play technology can be applied for legacy as well as new engine design. Any changes in sensors, actuators, or software in this system should be considered as a part of the modular design. For example, using existing hardware with new hardware with minimum changes in the software.

Appropriate embedded system design is also a part of the PnP technology development. This PnP technology has the potential to optimize the software/hardware integration for legacy and new generation turbine engines. New design approaches are needed in unmanned aerial vehicle (UAV) development, where small gas turbines are being used to power a variety of different lift/thrust devices. UAV development programs rarely have the resources for serious engine redevelopment and therefore must select from a limited number of commercial off the shelf (COTS) engines. In the case of small gas turbines, these COTS engines are generally designed for missile-turbojet or power generator applications, while the UAV designer may want to use the engine core in a turbo-prop or turbofan application. Successful development of PnP technology for this class of engines would allow UAV designers to purchase engines with onboard controllers and mate them with their own proprietary fan/prop sections without having to design a new control system from scratch. Some of the potential examples of propulsion systems for PnP technology application are presented here. In a UAV which has a few different propulsion systems in which they have had to integrate commercial power systems into the overall propulsor, either using one fan or several fans. Another application is a UAV which has an engine attached to a lift fan; the fan is fixed pitch and the motor is internal combustion, but a turbine application would require the incorporation of a variable pitch fan system. Another example could be the Pratt and Whitney (P&W) pure power geared turbofan engines which have been developed recently. The current versions of the engines utilize fixed pitch fans, but PnP technology can enable the integration of variable pitch fans in P&W geared turbofan engines.

Gas turbine engine technology is a core element of many naval operations, including airborne assets and vessels relying on gas turbine propulsion technology. This plug and play technology could optimize the software/hardware integration for legacy and new generation turbine engines.

Structuring engine control in a modular fashion using PnP technology would increase compatibility between different engine manufacturers and reduce development time and cost for new engines. PnP engine control technology also offers the potential of reduced engine weight, complexity, and maintenance needs, it also increases the flexibility in engine control systems. In addition, this architecture increases the reconfigurability/upgradability of propulsion systems where the data-bus, individual sensors and actuators, as well as computers, can be replaced and, possibly, updated, without forcing the disassembly/re-assembly of many engine components.

PHASE I: Conceptual development of the PnP technology which includes the decentralized adaptive controller with a self-tuning control loop to be used for engine core and fan/prop subsystems and numerical simulation of this



technology for a small turbofan engine. This stage is mostly focused on the software and simulation aspect of PnP technology development.

PHASE II: The outcome of the first task would then be validated on a representative turbine engine, by investigating the necessary hardware and implementing the developed PnP technology. Based on the results of this experiment, update the controller architectures as necessary. Working with turbine engine manufacturers is encouraged.

PHASE III DUAL USE APPLICATIONS: Integrate the outcomes of the Phase I and II tasks in a finalized software and hardware platform and develop it as a PnP technology for modular propulsion systems. This technology can be tailored for any propulsion system in manned or unmanned aircraft such as gas turbine, hybrid-electric engine, or piston engine specifically.

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KEYWORDS: Plug-and-Play (PnP), Modular Design, Decentralized Control Architecture, Adaptive Control, Turbine Engine, Propulsion Systems, Online Control Tuning, Reconfigurable System

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AF192-040 TITLE: Development of a High Performance, Printed Conformal Li Battery

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: --

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

OBJECTIVE: Develop and demonstrate a high-performance, rechargeable, printed, solid state battery with a specific energy >250 Wh/kg at a C/5 rate. The battery must maintain >500 cycles over an operating temperature range of 0 degrees C to 50 degrees C with humidity conditions ranging from 0 to 100 percent while sustaining a high level of

performance.

**DESCRIPTION:** The emphasis of this topic shall be on the development of aerosol jet, inkjet printing, syringe deposition or non-vacuum deposition technologies to demonstrate printed all-solid state batteries with a specific energy >250Wh/kg at a C/5 discharge rate, and an objective 4 Ahr cell size. The cell should be capable of maintaining a constant discharge rate up to 2C, as well as, have the ability to operate under these conditions over a wide temperature (0 degrees C to 50 degrees C) and humidity (0 to 100 percent) range.

The Battlefield Air Operations (BAO) Kit's capability description document (CDD) provides many key performance parameter (KPP) and key system attribute (KSA) requirements addressed in this project. The focus of this project is to provide battlefield airmen (BA) with a safe, energy dense power source for dismounted missions. The BA worn system is only one of many military assets relying on rechargeable batteries as their power source. There continues to be an increasing need for batteries with more electrical energy and power as the capabilities for these systems continue to improve. The increasing need for additional batteries to support these growing power and energy demands comes with added weight and mounting space limitations. The BA can carry in excess of 30 lbs. of batteries, including BB-2590s, to support a single mission.

Solid state battery technology is one approach toward enabling the use of high energy-dense electrode materials, which will help limit the weight of the batteries the warfighter will need to carry, while providing a safer Li-ion battery solution. One of the limiting factors for solid state batteries is the high interfacial charge transfer resistance between the electrodes and electrolyte, as well as the conductivity of the electrolyte. This limits operation at lower temperatures and high discharge rates (up to 2 degrees C). Solid state batteries provide the opportunity of increased cycle life and shelf life with dendrite formation and growth suppression. In addition, solid state batteries may enable the utilization of high voltage / high energy electrode options since solid state electrolytes are known to exhibit good electrochemical stability and a wide electrochemical window, thus further improving the energy density.

The focus of this effort is to explore the use of 3-D printing mask-less deposition techniques, such as aerosol jet, inkjet printing, syringe deposition, or non-vacuum deposition technologies as a potential approaches to provide intimate contact between electrode and electrolyte layers, which will address the interfacial charge transfer resistance. 3-D printing techniques provide the ability to functionally engineer the cell layers, as a mean to lower interfacial charge transfer resistance, thereby improving Li-ion transference, cycle life, as well as, overall battery performance. Furthermore, the ability to use a more automated 3-D printing processing technique could not only enable the solid state battery technology to be readily scaled to a range of cell sizes but also reduce manufacturing costs. This will allow for the realization of solid state batteries which can provide a safer, more robust product for the warfighter in comparison to the current conventional cells which contain a volatile liquid electrolyte.

**PHASE I:** Design and define performance parameters/integration constraints for the battery. Demonstrate feasibility of a printed solid state battery. Demonstrate overall performance improvements when compared to a common lithium ion battery. Provide testing to prove safe and reliable charge/discharge capabilities, and performance in various temperature (0 degrees C to 50 degrees C) and humidity conditions (0 to 100 percent).

**PHASE II:** Develop and demonstrate a prototype 4Ah solid state 3-D printed cell with the ability to meet the stated metrics above. Demonstrate and validate the ability to meet required performance. Demonstrate the safety improvements and the operational conditions, structural robustness, and energy/power efficiency to meet design metrics. Conduct a formal risk assessment of the printed solid state battery, projected cost analysis for manufacturing, and document key program risks. Deliver a prototype printed solid state battery to AFRL for testing and analysis.

**PHASE III DUAL USE APPLICATIONS:** Mature technology and produce representative articles for operational test assessments. Submit production representative articles for certification. Provide operator and maintainer manuals. Develop and refine cost and schedule estimates for full rate production.

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2. Gu, Y., et al., "Fabrication of rechargeable lithium ion batteries using water-based inkjet printed cathodes," Journal of Manufacturing Processes 20, 198-205 (2015).

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KEYWORDS: Solid Electrolyte, Aerosol Jet, Inkjet, Additive Manufacturing, Rechargeable Solid State Battery, Battlefield Airman, Safety

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AF192-041 TITLE: Erosion Resistant Coatings for Large-Diameter Gas Turbine Engine Compressor Integrally-Bladed Rotors (IBRs) and Lift-Fan Blades

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: --

OBJECTIVE: Develop and apply erosion-resistant coatings to F-35 lift fan blades and/or large-diameter integrally-bladed rotors (IBRs).

DESCRIPTION: Aircraft operating in sand/dust environments experience erosion of the gas turbine engine compressor airfoils that deteriorates engine performance; increases fuel consumption; increases maintenance, logistic support, and costs; and decreases safety-of-flight. The Joint Strike Fighter F-35B Short Take-off and Vertical Landing (STOVL) aircraft will operate in desert environments and ingest abrasive particles during the critical take-off and landing stages of operation. While the implementation of inlet barrier filters has been applied to helicopter engines to offer some protection to their compressor airfoils, this solution will not help the F-35B lift fan blades, which are directly exposed to the full force of any dust or debris that may be kicked up from the ground during lift-off and landing. The successful application of erosion-resistant coatings that are designed to handle those particular conditions will be key to sustaining safety of flight and aircraft system performance. Historically, erosion-resistant coatings have also been applied to helicopter engines operating in desert environments and have resulted in increased engine time-on-wing and engine performance retention. Erosion-resistant coatings have been applied on helicopter engines with compressor airfoils measuring no greater than 10 cm in length. The compressor airfoils on the JSF aircraft's IBRs for both the STOVL lift fan and cruise engines for all three F-35 variants are much larger than compressor airfoils on helicopter engines. For example, a first-stage IBR can measure approximately one-meter in diameter. These large-size IBRs are expensive to manufacture and replace; hence the potential of an erosion-resistant coating maintaining component efficiency and delaying component degradation of large-diameter IBRs will be critical in reducing total operating costs. A previous SBIR topic (N08-144) focused on developing an erosion-resistant coating with damping properties for the compressor airfoils on the JSF aircraft's integrally bladed rotors (IBR), but was not pursued. This project seeks erosion-resistant coatings that can be applied on much more vulnerable gas turbine engine lift fan blades and main engine IBRs on a production basis. The coatings must be able to withstand the austere operating environments of gas turbine engines such as high cycle fatigue (HCF) and stresses due to surge and aerodynamic and centrifugal loads. At the same time, they should not spall or delaminate after absorbing foreign object damage.

PHASE I: Determine the feasibility of applying erosion-resistant coatings on large-diameter engine fan/compressor IBRs and lift fan blades on a production basis.

PHASE II: Demonstrate the application of the coating on a large-diameter IBR and/or lift fan blade. Conduct erosion tests on current bill-of-material and coated large-diameter IBRs and/or lift fan blades to characterize the baseline erosion rates. Demonstrate that the coating process for large-diameter IBRs and/or lift fan blades is ready for application on a production basis. Provide non-recurring and recurring costs to apply production coatings, and

predict savings and benefits for F-35.

PHASE III DUAL USE APPLICATIONS: Transition application of the selected erosion-resistant coatings to the JSF engine compressors.

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KEYWORDS: Erosion; resistant; coatings; airfoils; lift fan blades; gas turbine engines

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AF192-042 TITLE: Advancement of High Energy Rechargeable Lithium Batteries

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: --

OBJECTIVE: Develop and demonstrate a novel high energy (>400Whr/kg) rechargeable lithium battery technology to provide high quality enduring power for Battlefield Airmen wearable electronics and small unmanned aerial system (SUAS) applications.

DESCRIPTION: The focus of this project is on providing Air Force Special Operations Command (AFSOC) battlefield airmen (BA) with a high performance, energy-dense power source for extended runtime on dismounted missions. A significant number of military assets, including multiple types of soldier-worn systems, rely heavily on power provided by rechargeable batteries. As the capabilities of these systems increase to support current and future mission sets, there is an ever-increasing need for batteries with more electrical energy. Recent advancements in high energy electrode chemistries (e.g. Lithium metal anode, Silicon anode, nanostructured high energy cathode materials) have proven feasible for achieving specific energy densities (i.e. increased amount of stored energy for the equivalent weight) in excess of 400 Whr/kg, or approximately a 1.6X improvement over state-of-the-art Li battery technology. Specifically, lithium metal has always been considered as a "Holy Grail" of anode materials for high-energy-density batteries owing to its extremely high theoretical gravimetric capacity of 3860 mAh/g and the lowest electrochemical potential of 3.04 V. Unfortunately, significant safety challenges still exist, including dendrite growth and complex interfacial reactions, which have limited its transition to practical applications. The objective of this topic is to develop and demonstrate a novel rechargeable lithium battery with a specific energy >400 Whr/kg at C/5 discharge rate, able to maintain an objective cycle life of >250 cycles at 80 percent capacity and operate over a wide temperature range of -30 degrees C to + 49 degrees C and varying humidity conditions (0 to 100 percent). The high energy cell should have the ability to operate up to a 2C continuous discharge rate at the stated operational conditions, as well as be stored over a wide temperature range -40 degrees C to +70 degrees C. A strong focus will be on optimization and maturation of the technology for military use and safety. This topic will not consider the use of lithium sulfur or metal air batteries as proposed solutions.

PHASE I: Design and define performance parameters/integration constraints for the battery. Demonstrate feasibility achieving the stated metric on the proposed high energy battery solution. Demonstrate overall performance

improvements when compared to a common lithium ion battery. Provide testing to prove the ability to achieve safe and reliable charge/discharge capabilities, cycle life, and performance.

PHASE II: Develop and demonstrate the high energy Li battery solution at a cell capacity of at least 4Ah, with the ability to meet the stated metrics above. Demonstrate and validate the ability to meet stated design metrics above. Develop test plan and conduct laboratory testing to confirm performance. Conduct a formal risk assessment of the high energy battery solution for transportation, storage, and use in an operational environment, perform a projected cost analysis for manufacturing, and document key program risks, as well as risk mitigation steps. Deliver a prototype high energy rechargeable Li battery cells to AFRL for testing and analysis.

PHASE III DUAL USE APPLICATIONS: Mature technology and produce prototype battery packs for operational test assessments. Submit production representative articles and pass UN/DOT and MIL-STD-810G testing and certification. Develop and refine cost and schedule estimates for full rate production.

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KEYWORDS: High Energy Lithium Battery, Rechargeable Lithium Battery, Secondary Lithium Battery, High Energy Battery Electrodes, Energy Storage, Portable Power

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AF192-043            TITLE: High Performance Solid Rocket Propellant Replacement

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: EELV - Evolved Expendable Launch Vehicle

OBJECTIVE: Design and develop a form-fit-and-function replacement for Aluminum in Ammonium Perchlorate Compound Propellant (APCP) solid rocket propellant that produces minimum HCl and aluminum slag bi-products while maintaining equivalent or better combustion efficiencies ( $c^*$ ), and maintaining or improving munition safety rating. Minimize performance degradation due to water condensation on proposed fuel grain during storage, transportation, and flight operations.

DESCRIPTION: High performance solid rocket propellants currently have two primary problems: the metal fuel (aluminum powder) sinters and agglomerates at the propellant surface, forming large molten droplets (LMD) which burn slowly and cause significant two-phase flow losses as the LMD pass through the nozzle; and they use ammonium perchlorate as an oxidizer, which also forms copious amounts of corrosive hydrochloric acid (HCl) during combustion. These bi-products are harmful to the atmosphere, and degrade the space environment by producing debris in the form of Al slag which can co-orbit and collide with resident space objects.

Some replacement fuels have yielded propellants that have reduced performance (lower specific impulse), only work

at low altitudes, and/or become unsafe to handle (detonable). For air-launched missile applications, a munition may be loitered at a colder, higher altitude for an extended period of time; and then be returned to a warmer, low altitude environment. Condensation is likely to occur, resulting in the fuel being compromised.

PHASE I: Design a solid rocket fuel propellant to replace the current fuel used in munitions and rocket boosters which reduces degradation due to water condensation, maintains or improves munition insensibility, and produces thrust equivalent to or greater than that of current solid rocket fuel propellants.

Major Milestone for Phase I is to assess the safety and material compatibility of proposed fuel material by itself and in relevant propellant formulations. This includes fully characterizing the material handling concerns and protocols. The overall objective of the Phase I work is to develop one to two candidate self-fragmenting structural reactive materials (SF-SRM) that can be used as a novel explosive ordnance casing material. This effort could include developing and manufacturing self-fragmenting, self-reacting materials (SF-SRM) for preliminary testing; testing the sensitivity of SF-SRM materials for electrostatic shock, friction, and drop-weight impact; investigating the microexplosive tendency of the candidate SF-SRM materials under high heating rates; and investigating the casing combustion efficiency of pellet size candidate SF-SRM powders under strong explosive shock.

PHASE II: Build and test, in a relevant environment, the above described solid rocket fuel propellant. Phase II milestones include determining burn rate and pressure exponent for a relevant formulation as well as determining small-scale ballistic performance and mechanical properties. Further, accelerated aging studies and cold-soak tests will be conducted to give an indication of shelf life.

PHASE III DUAL USE APPLICATIONS: Milestones will include formulation optimization, performance assessment under high-fidelity laboratory conditions, and engineering trade studies to assess the utility/benefit of the material based upon delivered density\*Isp.

Military Application: Use as a fuel replacement in a prototype solid rocket fuel rocket motor in a sounding rocket or small-scale missile. For air-launch, use in precision guided munitions propellant to ensure quick and reliable response to adversarial activities. Civilian Application: Use as a rocket fuel propellant replacement for civilian solid fuel rocket launches. Here, the reduction in HCl acid and Al slag is useful in minimizing the negative environmental impact, allowing more frequent launches.

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1. B.C. Terry, I.E. Gunduz, M.A. Pfeil, T.R. Sippel, and S.F. Son. "A mechanism for shattering microexplosions and dispersive boiling phenomena in aluminum–lithium alloy based solid propellant". <https://www.sciencedirect.com/science/article/pii/S1540748916301572>
2. Terry, B., Sippel, T., Pfeil, M., Gunduz, I., and Son, S., "Removing Hydrochloric Acid Exhaust Products from High Performance Solid Rocket Propellant Using Aluminum-Lithium Alloy", *Journal of Hazardous Materials* (2016).

KEYWORDS: APCP, solid rocket fuel propellant, rocket booster, munitions,

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AF192-044 TITLE: Propulsion for Agile, Resilient Spacecraft

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: N/A

**OBJECTIVE:** To develop innovative propulsion concepts that address the increasing agility requirements of Air Force and DoD spacecraft.

**DESCRIPTION:** Future DoD spacecraft will need greater agility to change orbits for mission requirements or to avoid the increasing hazards in crowded orbits. An agile spacecraft is one that can make an orbital change while maximizing propulsive life through propellant conservation. Agility requires, at minimum, propulsion concepts that are able to trade specific impulse (Isp) with thrust over a wide range as mission needs require. Short notice needs would require high thrust at the expense of propellant. Mission needs that have less severe time constraints can use high Isp and conserve propellant. However, a truly agile spacecraft will require both high thrust and high Isp simultaneously, at least for short periods of time.

This topic seeks to develop in-space propulsion concepts that can be operated for short periods of time at high Isp and high thrust simultaneously. By high thrust, it is meant that the thrust is higher than a typical Hall thruster but can be less than a typical spacecraft chemical thruster, on the order of a few tens of newtons. By high Isp it is meant that the Isp is much higher than a chemical thruster, on the order of 1000 seconds or higher. By short period of time it is meant that large orbital maneuvers can be made impulsively instead of by spiral changes. It is anticipated that successful SBIR efforts will take advantage of increasingly efficient, low mass batteries or ultra-capacitors while carefully managing system mass so that the spacecraft mass fraction does not become unreasonable. This topic is looking for responsive propulsion giving high delta-V more characteristic of chemical propulsion while using a small fraction of propellant that a chemical thruster would use. Offerors are encouraged to also suggest innovative orbital maneuver strategies that might be enabled from their proposed solution.

Current spacecraft propelled by electric thrusters use Hall thrusters that are too low in power to provide true agility. Additionally, current spacecraft do not have the power capability to supply a larger electric thruster. However, current energy storage devices could enable the use of high power electric thrusters using existing spacecraft photovoltaic systems. High thrust enables faster large orbit changes to mission altitudes. Once on orbit, a larger thruster could provide rapid acceleration and large delta-V with the use of energy storage. Current Hall thruster technologies may be a good fit at higher Isp, where many designs are approaching 70% efficiency, close to the limitations of physics. It is not as clear that Hall thrusters are a good solution at an Isp of 1000s or lower as their efficiencies drop off rapidly. Therefore, this topic will allow electric propulsion technologies other than Hall thrusters. Lower Isp allows higher thrust to power which would reduce orbit transfer times, yet be much more efficient in propellant than chemical thrusters.

Proposed solutions should also be compatible with typical DoD spacecraft. The possibility of spacecraft system contamination should be addressed. The proposed propulsion concept should not limit spacecraft lifetime, most of which have expected lifetimes of 15 years. No unusual thermal, power, or balance constraints should be placed on the spacecraft by the proposed concept.

**PHASE I:** Select propulsion concepts and identify how spacecraft agility could be improved by these concepts. A proof of concept demonstration is desirable. Technical challenges or barriers should be identified. An approach to a phase II effort should be outlined.

**PHASE II:** Further develop the Phase I effort by building and testing a prototype thruster or thruster system including a propellant feed system. Government Furnished test facilities and hardware may be available so the proposer should request if desired. Further interaction with Spacecraft Prime Contractors would be desirable.

**PHASE III DUAL USE APPLICATIONS:** Transition the technologies developed under this topic to a demonstration flight and space qualification.

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Green Propellants for Space Propulsion, Noordwijk, NL, June 2001.

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**KEYWORDS:** Electric Propulsion, MagnetoPlasmaDynamics (MPD), Spacecraft Propulsion, Advanced Propulsion, Magneto Hydrodynamics (MHD), Plasma

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AF192-045            **TITLE:** Advanced Integrated Engine Control Test Bed for Development of Intelligent Systems and Smart Instrumentation

**TECHNOLOGY AREA(S):** Air Platform

**ACQUISITION PROGRAM:** N/A

**OBJECTIVE:** Design and development of a cost-effective test bed capability or experimental setup for gas turbine engine control and sensor systems.

**DESCRIPTION:** Modern gas turbine engine designs are being influenced by increased levels of instrumentation and control that enhance the overall performance. Variable cycle engines have increased the level of authority that control system developers have over the engine cycle. The number of control variables and sensors have increased by over 50 percent. These advanced engine cycles require instrumentation feedback which then allows the digital engine controller to optimize the engine performance. The reliance on data dependency along with the continued decrease in price of electronics and instrumentation over the course of the last several decades has fueled this move toward more heavily instrumented engines. This, in turn, has led to significant improvements in instrumentation and control authority, resulting in innovative measurement modalities and control schemes. There is, however, a paucity of experimental testing infrastructure to adequately and reliably test control paradigms and distributed instrumentation in an actual gas turbine environment under nominal operating conditions. This is especially necessary since past development of sensors and control concepts is typically carried out with sub-scale experimentation which limits the testing of true actuator behavior. This lack of capacity to test equipment on an operating gas turbine presents an obstacle in the path towards developing new sensor and control technology that side-step issues of scalability, closed loop control and bottlenecks of bandwidth, frequency response and authority.

The USAF is seeking a new test bed / experimental setup to be designed and developed which will provide cost-effective testing for newly developed sensors, actuators or control schemes in support of USAF objectives. The new test bed should have multiple options for including traditional and novel sensor technologies in a variety of gas turbine type environments. This includes compressor inlet and discharge, turbine inlet and discharge, and even the combustion zone. The new system should also have a flexible control system that can be updated to include third-party control schemes to interact with the existing sensor and actuator network.

**PHASE I:** Design an experimental setup/test bed with the basic sensors and actuators typically found in gas turbine engines, and access for additional and nontraditional sensors and actuators for future application and testing of advanced control strategies. Design a control system to interact with the sensors and actuators to achieve basic engine control (start, steady state operation, transient throttle events, and shutdown), as well as, flexibility to experiment with other novel control strategies.



PHASE II: Fabrication and commissioning of the test bed/experimental setup to include demonstration of the full range of operating conditions as designed, including demonstration of the control modes of the test system.

PHASE III DUAL USE APPLICATIONS: Conduct performance testing of sensors, actuators and control schemes relevant to USAF turbine engines or other aerospace vehicle applications.

#### REFERENCES:

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KEYWORDS: gas turbine, engine controls, variable cycle, sensors, actuators, experimental setup

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AF192-046 TITLE: Passive Coatings for Aircraft Drag Reduction

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop an advanced riblet system (ARS) to reduce viscous drag on medium altitude long endurance aircraft (MALE) to increase range/time-on-station (TOS). Riblet application should be fast ( $m^2/min$ ), compatible with depot processes/timelines, and produce structures resistant to fouling.

DESCRIPTION: A significant source of aircraft drag is skin friction drag; the drag caused by the friction of air against the surface of an aircraft in flight. For a typical MALE aircraft the skin friction drag is about 1/3 of the total aircraft drag. Reducing skin friction is an obvious target for increasing aircraft performance (range or TOS).

MALE aircraft usually achieve their performance in part by having laminar flow boundary layers (BL) on some surfaces (e.g. wings); the skin friction of a laminar BL is an order of magnitude less than that of a turbulent BL. They are designed to have the maximum extent of laminar flow practical and achieving more would be extremely difficult. However there are technologies for reducing the skin friction of the remaining turbulent aircraft BLs. Riblets are one such technology.

2D riblets are sized (peak-to-peak and peak-to-valley) to exclude the turbulent BL flow structures (which have a characteristic spanwise dimension) from "scrubbing" a significant portion of the surface; resulting in the flight-proven 6 percent skin friction drag reduction. Since skin friction drag is about 1/3 of the total drag of a MALE aircraft a 6 percent skin friction drag is equivalent to 2 percent drag reduction at the system (aircraft) level. (Note that this is a theoretical maximum since it is not possible to apply riblets to 100 percent of the OML with a turbulent BL.)

2D riblets have been flight tested on an A320 transport aircraft with about 2/3 of the aircraft's surface covered with riblets. The A320 is typical of most Mil and Civ transport aircraft flying today; skin friction is approximately 50 percent of the total aircraft drag. With the 6 percent reduction in skin friction drag due to the riblets the total aircraft drag reduction achieved was 2 percent (2/3 x 50 percent x 6 percent). Despite the flight-proven 2percent transport aircraft drag reduction 2D riblets they have not transitioned to Mil or Civ aircraft because 1) excessive application time (current state-of-the-art (SOTA) is an adhesive-backed applique), and 2) limited duration (1-2 years) of the drag reduction effect due to the microscopic riblet grooves becoming fouled (dirt, hydraulic fluid, etc). Both of these factors have a negative impact on ROI, preventing transition.

The SBIR will address these transition hurdles. A direct contactless microfabrication method (DCM) will "print" the riblets into a photo-curable aircraft topcoat. Advanced (3D) riblets will be designed, yielding 2.5-times the skin friction drag reduction as current 2D riblets. Superhydrophobic coatings will be incorporated into the ARS to keep it clean and functional for an entire programmed depot maintenance (PDM) cycle. An ultra-precision drag balance will be developed to aid development and performance validation of the ARS. As such this SBIR will close the gap between the theoretical promise of riblet technology for skin friction drag reduction, and its practical application to the U.S. Air Force fleet. It is recognized the multifaceted aspect of this topic will make it challenging for a single small business.

**PHASE I:** Investigate DCM scale-up (ref 2) by examining use of multiple LEDs and assessing robotic- or gantry-based systems for optical head movement. Assess design variables for 3D riblets (ref 3) numerically (CFD) and develop experimental validation plan. Examine coating chemistries and refine aircraft-compatible application processes to improve the durability of superhydrophobic coatings (ref 4). Design an ultra-precision balance with milli-Newton resolution.

**PHASE II:** Design and fabricate a scaled-up prototype DCM system capable of applying 3D riblets to a major portion of an aircraft (wing or fuselage section) at speeds on the order of  $m^2/min$ ; mature 3D riblet designs with continued CFD simulations; use the DCM method to produce and wind tunnel test the ARS, using the ultra-precision drag balance designed in Phase I; create the superhydrophobic coatings with the chemistries and application techniques identified in Phase I. Validate the durability of the coatings using ASTM tests and determine thickness to adjust riblet dimensions to compensate.

**PHASE III DUAL USE APPLICATIONS:** Develop and commercialize a full scale DCM system capable of applying an ARS to military and commercial aircraft. The ARS will be comprised of optimized 3D riblets and Superhydrophobic coatings with effects lasting an entire PDM cycle (nominally 5 years). Commercialize the ultra-precision skin friction balance.

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2. Microfabrication of Riblets for Drag Reduction, AIAA-2018-0321.
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4. Designing Superhydrophobic Coatings for Aircraft Drag Avoidance, AIAA-2017-0282.

**KEYWORDS:** aircraft, drag, reduction, passive, viscous, skin friction, riblet, superhydrophobic, force, measurement

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AF192-047            TITLE: MQ-9 Battery Technology Improvements

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: PREDATOR/REAPER - Unmanned Aircraft System

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

**OBJECTIVE:** Develop a safe and low maintenance Li ion battery replacement for the MQ-9 unmanned aerial system (UAS), able to support a 365-day inspection interval in order to reduce aircraft downtime without degrading the current system specifications.

**DESCRIPTION:** The objective of this topic is to design and develop a lithium ion battery- based solution as a potential NiCd battery replacement as a means to minimize the sustainment requirements with a 365-day inspection interval objective, as well as increasing the power and energy available onboard the aircraft.

Unmanned aerial systems (UASs) have become an essential asset for U.S. military forces, and increasingly by allied forces, to help establish battlefield superiority in today's hot zones, allowing for more precise weapons targeting and better protection over friendly forces. The use of these weapon systems have and continue to provide unparalleled real-time information to the ground forces to support both the Global War on Terrorism and humanitarian relief missions. Therefore, any substantial aircraft downtime due to routine or unwarranted maintenance need to be minimized for optional..... Battery reliability and maintainability with the existing NiCd battery has become a substantial issue that can drive sustainment costs and aircraft downtime. Improving the overall efficiency and effectiveness of the battery with a new technology solution will not only reduce sustainment costs but can also help to improve the SWaP (size, weight, and power) as well as capacity. The primary focus of this effort shall be on developing a safe, sustainable battery solution, not only during operation, but also address the logistics challenges of any specialized transportation, storage, and handling requirements. UN/DOT 38.3 and Navy Instruction 9310 shall be used to determine reasonable lithium ion battery safety considerations. The solution should be as close to a form/fit/function replacement as possible. The existing NiCd battery specifications are as follows: nominal 25.2V (16.8V cut-off), 16Ah capacity, specific energy density 44.3 Wh/kg (cells only), volumetric energy density 836.1 Wh/L (cells only), max continuous discharge rate of 5C at the battery level, and nominal charge rate of C/3. The operating environment is -40 degrees C to +60 degrees C and 0 percent to 100 percent humidity, with a non-operating environment requirement of -40 degrees C to +70 degrees C. Aircraft design changes to enable battery compatibility should be kept to a minimum. Any changes required for integration of the battery solution shall be identified and documented.

**PHASE I:** Determine feasibility of replacing the MQ-9 battery with a lithium ion battery based solution design with a 365-day maintenance inspection interval, while improving upon the baseline battery metrics stated above. Demonstrate through testing a safe solution can be achieved during all operational and non-operational conditions. Evaluate logistics impacts on the current MQ-9 transportation and storage infrastructure. Develop a plan to ensure battery replacement meets all required specs, identifying technical challenges and how these can be overcome.

**PHASE II:** Develop and demonstrate Li ion-based MQ-9 battery, with the ability to meet the stated metrics above. Develop test plan and conduct laboratory testing to confirm safety and performance. Safety testing shall be performed in accordance with UN/DOT 38.3 and Navy Instruction 9310. Conduct a formal risk assessment of the battery solution for transportation, storage, handling and use in an operational environment, perform a projected cost analysis for manufacturing at full-rate, and document key program risks, as well as risk mitigation steps. Identify any impact replacement battery would have on current aircraft design, including software/hardware. Deliver a prototype Li ion battery to AFRL for testing and analysis.

PHASE III DUAL USE APPLICATIONS: Fully mature technology replacement battery technology utilizing the structured MQ-9 upgrade strategy, to include providing drawings, delta specs, LG analysis, HW/SW Mx IETMs, etc. Submit production representative articles and pass UN/DOT 38.3 and MIL-STD-810G testing and certification. Once criteria is met, the solution may become a candidate for integration onto the platform. Develop and refine cost and schedule estimates for full rate production.

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2. MIL-STD-810G, DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS (15-APR-2014). [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810G\\_CHG-1\\_50560/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810G_CHG-1_50560/).
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KEYWORDS: Aircraft Lithium Battery, Rechargeable Lithium Battery, Secondary Lithium Battery, Unmanned Aerial Vehicle, Energy Storage, Battery Safety

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AF192-048            TITLE: Hypersonic Vehicle Electrical Power Generation through Efficient Thermionic Conversion Devices

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: N/A

OBJECTIVE: Develop thermionic generation device technology that will take advantage of the extreme temperature within a hypersonic platform resulting in efficient thermionic conversion into electrical power while existing in a modular package to survive the harsh environment.

DESCRIPTION: Thermoelectric generators (TEG) and Thermo-photovoltaics (TPV) are common candidates for energy harvesting studies, but the extreme internal temperature profile within a conceptual scramjet driven hypersonic vehicle presents a challenging design issue for TEG or TPV integration. Conceptual hypersonic aircraft are generally designed to be propelled by a non-rotating engine, such as a scramjet, prohibiting the use of conventional generators to draw electrical power from the engine. This fact, coupled with the extreme temperatures associated with hypersonic flight, has prompted studies of thermal-to-electric conversion of the excess heat energy on a hypersonic vehicle to provide electrical power to onboard systems. An alternative conversion technology that is especially attractive at higher temperatures is thermionic energy conversion. Thermionic devices have proven to provide high efficiency conversion from an extreme temperature source above 1800K and a reservoir "low" temperature in excess of 1000K. A thermionic energy conversion device consists of two metal electrodes separated by a narrow gap, where the high temperature emitter thermionically emits electrons into the gap and the collector absorbs them. This proposed program should address the application of modular thermionic conversion devices to convert internal heat within a hypersonic vehicle to electricity. The program should consider recent developments in micro-manufacturing and materials to reduce the interelectrode gap distance within the converter device and

potentially eliminate the need for cesium vapor while suppressing the space charge effect. Device design should account for the harsh environment that includes high temperature and exposure to an oxidizing atmosphere and/or liquid fuel. Device operating temperatures should be explored between 1800K-2200K (emitter) and 800K-1200K (collector) with the potential for the temperature profile changing with time. The lifetime requirements could vary from a single use to a reusable system with 1 hour of power generation per use. The thermionic device power output goal would be 1-10 W/cm<sup>2</sup>, which could be modularized to produce 10-100 kW of electrical power over 1 m<sup>2</sup> of surface area within the hypersonic vehicle.

The work functions of the emitter and collector surfaces must be relatively low to develop a functional potential difference across the gap and draw electrical current through a load. The electron current through the gap can create a negative space charge which self-limits the current, so the negative space charge must be suppressed through device engineering. Significant engineering efforts were conducted in the 1960's in the USA and Soviet Union to integrate thermionic conversion devices to space nuclear reactor or solar concentrator platforms for long duration operation. Typically, these devices included cesium vapor within a gap of ~0.1 mm to suppress the space charge and reduce the surface work functions. Thermionic conversion technology was demonstrated as feasible, but further development was curtailed for programmatic reasons.

PHASE I: Design a thermionic conversion module that could operate for 1 hour within the high temperature and oxidizing environment of a hypersonic vehicle with a power output density >1W/cm<sup>2</sup>.

PHASE II: Fabricate and test thermionic conversion modules in simulated hypersonic vehicle operating conditions measuring power output and lifetime characteristics with the goal of 1 hour of operation at >1W/cm<sup>2</sup>. Deliver prototype module to AFRL/RQQE.

PHASE III DUAL USE APPLICATIONS: Dual use commercialization: Explore military use applications of power generation for reusable hypersonic vehicles. Potential commercial applications could include direct conversion of fuel heat for remote electrical power with higher energy density than batteries.

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KEYWORDS: thermionic, hypersonic, direct energy conversion, work function

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AF192-049 TITLE: Data Science Based Approaches for Modeling Optimal Controls and PHM for Power and Thermal System Components.

TECHNOLOGY AREA(S): Information Systems

ACQUISITION PROGRAM: F-22 - RAPTOR Advance Tactical Fighter

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

under US Export Control Laws. Please direct ITAR specific questions to the AF SBIR/STTR Contracting Officer, Ms. Michele Tritt, michele.tritt@us.af.mil.

**OBJECTIVE:** Develop model order reduction strategies for electrical power and thermal components that retain high accuracy with reduced computational time for real time control and health monitoring applications.

**DESCRIPTION:** Design and Verification of advanced propulsion and electric power controls requires reduced order models (ROMs) that run in real time. Calculation of power utilization, load factors, parameter estimates, and control mechanisms is a challenge as accurate, predictive algorithms may take an order of magnitude more time to execute (versus clock time) to reach a stable solution. It is desirable to reduce this computational burden to allow real time use of novel algorithms in control systems Propulsion Health Monitoring (PHM), and power and thermal architectures. It has been demonstrated that computational statistics (CS), machine learning (ML), and related artificial intelligence (AI) techniques that access large data sets can learn constrained domains without explicit programming. They can capture a large percentage of the requirements for accuracy of complex component and system loop (feedback) models of waste heat and transient power flow for electric actuation and high electric power usage components such as diode/fiber lasers. Use of key AI techniques such as CS and ML have the potential to reduce model/algorithm execution time by one or more orders of magnitude compared to the state-of-the-art.

In the Phase I program, it is desirable to employ an Artificial Intelligence (AI) machine learning techniques to develop an integrated ROM for use in simulations of power and heat flow networks (feedback loops), electric actuation controls, and high power electric loads. The ROM should incorporate suitable component specific transient (high order) power and thermal sink characteristics expected in operational scenarios. The research should explore acceptable processing execution speed versus accuracy over the domain of interest. The ROM should consider future compatibility with relevant system demonstration hardware, such as execution on an engine control verifier bench, which interfaces a FADEC, and other real-time hardware in a closed loop.

**PHASE I:** Select an AI machine learning methodology for prototype development of a Reduced Order Model (ROM) for control of high power electrical component energy flows (such as actuation, lasers) and waste heat. Ensure that the transient quality (high order effects) of the waste heat and electric power is considered. Evaluate suitable software and hardware architectures that reduce computational burdens, delays and communication uncertainties. Compare the performance of the ROM with a baseline representation of the system or component to determine the performance benefits and suitability for real-time applications. Participate in a workshop with the stakeholder (including all potential users of the tool) to insure that all requirements for the future prototype are clearly understood.

**PHASE II:** Relevant modeling software will be coded, refined, and tested based on the Phase I design. Demonstration of the real-time high fidelity modeling capability will be performed on a state-of-the-art closed loop control system bench. Limitations and potential operational issues will be documented, as well as, applicability to targeted advanced propulsion, power and thermal systems. Develop a training manual and a transition plan to facilitate use of the tool in the design process by an engine or airframe company.

**PHASE III DUAL USE APPLICATIONS:** Implementation and integration of the high fidelity capability will be accomplished. Real time and other performance issues with the Phase II design will be addressed and a fielded capability will be developed that meets the engine/aircraft power and thermal control system or thermal component operational requirements. Provide training to those identified in previous phases to accelerate transition to the field.

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2. Neal Dawson-Elli, Seong Beom Lee, "Data Science Approaches for Electrochemical Engineers: An Introduction through Surrogate Model Development for Lithium-Ion Batteries," Journal of the Electrochemical Society (2018).

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**KEYWORDS:** Control Optimization, Machine Learning, Data Science and optimization, power and thermal optimal control, AI Methodologies in Optimal Control, Supervisory Control Techniques

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AF192-050            TITLE: New Methods, and Technologies Required for Heat Rejection from Next Generation Aircraft

**TECHNOLOGY AREA(S):** Air Platform

**ACQUISITION PROGRAM:** F-22 - RAPTOR Advance Tactical Fighter

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

**OBJECTIVE:** Future aircraft-based high energy systems will produce hundreds of kilowatts of low-quality waste heat. So it is critical to integrate high energy system with propulsion, power, thermal, and controls for next generation aircraft. Novel approaches are sought to remove waste heat under these conditions without significant impacting the aircraft signature/aerodynamic performance.

**DESCRIPTION:** The large quantities of low-quality (<40 degrees C/104 degrees F) 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 20 degrees C - 30 degrees C (68 degrees F - 86 degrees F) 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 energy systems, 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 <40 degrees C/104 degrees F at altitudes from 10kft to 40kft. It has a good potential on improving the performance of commercial aircraft.

**PHASE I:** It will conduct a feasibility study on examining heat sinks involving a variety of technologies (propulsion, electric power, and thermal), evaluating them for performance, heat removal potential, SWaP, efficiency and effect on the aircraft 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. The SBIR Company will be working with an industry partner

(i.e. engine manufacturer or aircraft manufacturers).

PHASE II: Based on Phase I feasibility study on heat rejection/sink results 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 at Wright-Patterson AFB OH may be able to provide testing facilities for prototype system. The contractor may require base support during performance. Only U.S. Citizens will be permitted to work within AFRL Facilities.

PHASE III DUAL USE APPLICATIONS: Demonstrate the prototype system on a compatible aircraft with a suitable directed energy system or surrogate heat source. Complements work on an initial demonstration of a high-powered laser pod to be flown on advanced aircraft in 2021 time frame.

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KEYWORDS: Propulsion, Power, Thermal management, Directed Energy, Aircraft Heat Sinks, Low-Compatible, Integration, and Waste Heat

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AF192-051 TITLE: Optically Gated, Wide Bandgap Semiconductors for Aircraft Electrical Actuator Motor Drives

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: N/A

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

OBJECTIVE: Develop direct optically controlled, 1,200 to 2,000 V, 10 to 120 A, wide bandgap power switching device for applications in electro-hydrostatic (EHA) and electro-mechanical (EMA) actuator motor drives for air platforms.



**DESCRIPTION:** Due to the inherent immunity of photonic technology to dynamic electromagnetic events, its application to power electronics used to drive flight-critical EHA and EMA surface control actuators is predicted to increase the reliability and survivability of these subsystems dramatically. Wide bandgap (WBG) power device technology has been under development for several years, targeting applications in DoD power communication systems requiring high-reliability and harsh-environment operability. Wide bandgap materials quantified power device performance benefits, in addition to its high temperature capability, include; improved component efficiency through reduced on-state and switching losses, lower on-resistance for high voltage devices, and higher frequency switching capability. As such, wide bandgap semiconductors are an emerging high reliability power device technology slated for utilization in several DoD platforms.

Conventionally, passive and active filtering is used to reduce drive control susceptibility to large voltage and current switching transients and for suppression of parasitic oscillations inherent to electronic motor drive systems. However, these filters are incapable of protecting either the signal-level control electronics or the power devices themselves from catastrophic failure when exposed from external events and account for a significant volume and weight of the EHA/EMA electronics system. Optically-gated power semiconductors can minimize or eliminate the noise susceptibility of conventional power drive electronics. A successfully developed and fielded optically controlled EHA or EMA flight surface control subsystem could dramatically increase the survivability of air and other DoD platforms. An additional benefit is the possibility of reducing the volume and weight associated with conventional filters used to protect low-voltage control devices from the inherent radiated EMI associated with switching large voltages and currents.

Lightweight, rugged, and compact optical sources that satisfy the requirements of repetition rate, optical power, and wavelength are required for direct device triggering. High device gain translates directly to reduced optical triggering power requirements thereby reducing the cost and operational complexity of the optical source. Therefore, considerations pertaining to the optical source and driving mechanism significantly impact the suitability of an optical power switch to satisfy the power system architecture specifications in a given platform. In order to make overall system efficiency comparable to state-of-the-art electrically controlled WBG power electronics, it is desired that a 1200 V switch requires less than 2 W of optical power per amp of continuous current. Research is also likely needed to develop an appropriate opto-electrical packaging scheme that reduces the triggering power loss and that can handle harsh environmental conditions.

In summary, this topic is intended to investigate the area of optical control of wide bandgap power devices as it relates to power utilization and control technology that will satisfy stringent environmental requirements. The objective is to identify and address specific technology limitations and pursue solutions based on sound physical principles, which can lead to the development of robust, optically controlled power technology that can be utilized in EHA/EMA motor drives and other electrical power applications on DoD platforms.

**PHASE I:** Demonstrate the feasibility of new and innovative wide bandgap direct optical switching power devices. The development of a fundamental switch structure design, with the fabrication and characterization of a scaled prototype, is highly desirable. The device should block at least 1000 V and conduct greater than 10 A of current. The temperature capability of the device should support operating at 150 degrees C.

**PHASE II:** Develop and optimize full-scale, prototype, optically triggered wide band gap switches. Perform detailed static and dynamic electrical and optical characterizations of switch performance. Develop package design for optical integration and high power handling. Successfully integrate the prototypes into a representative power electronic component (converter, inverter, motor drive, etc.) for an equipment-level demonstration of the desired functionality using only optical control signals.

**PHASE III DUAL USE APPLICATIONS:** Military application: This technology could lead to insertion in a variety of military applications. Potential aviation applications include directed energy weapons, motor drives, power converter, power inverters, and other representative power electronic components.

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KEYWORDS: fly-by-light, power-by-wire, photonics, power electronics, wide bandgap device, optical isolation, gallium nitride semiconductors, electrical actuators, high electric field protection, EMI

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AF192-052 TITLE: Additively Manufactured Reactor For high performance, non-toxic monopropellants

TECHNOLOGY AREA(S): Space Platforms

ACQUISITION PROGRAM: --

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

OBJECTIVE: Develop and demonstrate an additively manufactured reactor for a 1N AF-M315E thruster.

DESCRIPTION: The last decade witnessed a tremendous rise in additive manufacturing capabilities. Today, numerous companies specializing in additive manufacturing are now capable producing complex parts from a variety of materials, including platinum group metals. This relatively new capability is of particular interest to the spacecraft propulsion community. Additive manufacturing of platinum group metals enables the creation of custom, complex, and often times small parts which may have been too expensive, complex, or outright impossible to create using traditional machining methods [1].

One such mechanism where additive manufacturing can play a pivotal role is in the development of reactor beds for monopropellant thrusters. The reactivity and stability of monopropellant reactor beds are the primary factors driving a thruster's operational lifetime. State-of-the-art (SOTA) monopropellant reactor beds employ the use of granular catalysts, which degrade and shift over the thruster's life. The degradation and shifting of granular catalysts results in a longer thrust rise time and increased chamber pressure oscillations. If these effects become too drastic, the thruster may no longer meet mission requirements and thus reach its operational end of life [2].

Additive manufacturing can offer technical solutions to replace and improve upon SOTA granular catalysts. Reactor beds which are additively manufactured can not only mitigate the issues of degradation and shifting plaguing SOTA granular catalysts, they can also be optimally designed for the various reaction stages taking place within the reactor. An optimized printed reactor bed has the potential to lead to better ignition characteristics, improved stability, a wider range of operational conditions, and increased lifetime. This solicitation seeks the development of an additively manufactured AF-M315E reactor bed for a 1N thruster. To maximize the likelihood of transition, the

reactor bed should be optimized to provide an operational lifetime of approximately 40 hours and be capable of delivering a minimum impulse bit of 15mN-sec.

PHASE I: Perform proof-of-concept analysis and experiments demonstrating the feasibility of the proposed reactor bed. Analysis and experiments should show practical manufacturability and performance/lifetime improvements over SOTA granular catalysts.

PHASE II: Develop an additively manufactured reactor bed for a 1N AF-M315E thruster with the objective of achieving TRL 5 by the end of Phase II activities.

PHASE III DUAL USE APPLICATIONS: Develop a 1N AF-M315E thruster incorporating the additively manufactured reactor developed under Phase II.

#### REFERENCES:

1. Beyer, S., "Hot Firing of World's First 3D-Printed Platinum Thruster Chamber," Airbus Defense & Space, ESA Space Engineering and Technology, June 15, 2015.
2. McRight, Patrick, et al., "Confidence testing Of Shell-405 and S-405 Catalysts In a Monopropellant Hydrazine Thruster." 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit. 2005.

KEYWORDS: Spacecraft Propulsion, Chemical Propulsion, Additive Manufacturing, AF-M315E, Catalyst

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AF192-053 TITLE: Development of High Energy Software Control System

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: F-22 - RAPTOR Advance Tactical Fighter

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

OBJECTIVE: Future aircraft with high energy demands will have very high peak heat loads, current draws and fast transients. We need to develop innovative novel software tools/approaches. They are sought to manage electrical and thermal subsystems at platform level.

DESCRIPTION: High energy airborne systems are expected to reach 150 kW (optical) within a few years. These systems will have peak electrical power draws in excess of 500 kW, peak thermal loads in excess of 400 kW and will be subject to fast transients at the beginning and end of a laser shot, as well as, in the middle of a laser shot. The lasers are expected to be laser diode pumped. The pump diodes themselves have very fast turn-on times while the electrical generation and heat removal systems have much slower turn on times. For overall energy efficiency, it is desired to have as low a quiescent power draw as possible. State-of-the-art high energy laser diodes are typically cooled below 30 degrees C (86 degrees F), this may change in the near future to 50 degrees C (122 degrees F) or higher. The successful proposal will develop

software tools/systems capable of controlling electrical and thermal management subsystems subject to the timing of pumps, generators, valves, laser diodes, laser gain media, turrets and other components of airborne laser weapon systems to meet the operational demand signal. The proposal may discuss the Size, Weight, Power and Cost (SWaP-C) of components, sub-systems testing etc. These studies on new methods and technologies will have a good potential on improving the performance of commercial aircraft.

PHASE I: It will conduct a feasibility study and develop a high energy software control system capable of managing the electrical and thermal aspects of partner company's laser weapon system (LWS) model. The SBIR company will select a LWS model from an industry partner (weapon system contractor/engine companies, laser diode/laser source companies) and develop the software system capable of managing electrical and transient thermal challenges/issues. The SBIR company will participate in a workshop with stakeholders to insure requirements for prototype control system are clear.

PHASE II: It will test the software control system on laboratory subscale prototypes or representative hardware to demonstrate successful platform – high energy system integration. Develop training manual and training plan to facilitate transition to the field.

PHASE III DUAL USE APPLICATIONS: Demonstrate the Laser software control systems integration on a compatible aircraft platform. Provide training to stakeholders to accelerate transition to the field. Effort will complement an initial flight demo of high-powered laser pod on advanced tactical aircraft.

#### REFERENCES:

1. Hitzigrath, R., "Improving Aircraft Fuel-Thermal Management," SAE Technical Paper 932086, 1993, doi: 10.4271/932086.
2. Gray, Charles N., and Shayeson, Maurice W., "Aircraft Fuel Heat Sink Utilization," <https://apps.dtic.mil/dtic/tr/fulltext/u2/912902.pdf>
3. Karimi, Kamiar J., PhD, Senior Technical Fellow, "Future Aircraft Power Systems - Integration Challenges," Carnegie Mellon University Press, 2007.
4. Swain, E.F., "Aircraft Avionics Cooling, Present and Future," Proceedings of the IEEE 1998 National Aerospace and Electronics Conference, 1998. NAECON 1998.

KEYWORDS: Propulsion, Power, Thermal management, Laser, Directed energy, Aircraft Heat Sinks, Low- Compatible, and Weapons

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AF192-054 TITLE: Small High Reliability Electrical/Signal Connectors for Gas Turbine Engine Applications

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: F-35 - Joint Strike Fighter (JSF) Program

OBJECTIVE: Develop novel electrical connector and contact designs that offer reduced footprint and increased reliability and durability over standard electrical connectors used in harsh environments.

DESCRIPTION: Electronic systems that operate in harsh environments are interconnected using a variety of circular and rectangular connector designs, often specified by MIL standards. They are a significant contributor to system upsets, both total and intermittent. State-of-the-art (SOTA) electrical connectors fail by combinations of opens (61

percent), shorts (16 percent), or intermittent connection (25 percent). Three basic mechanisms lead to failures that include, high cycle fatigue (HCF), tribology, and high temperature (over 150 degrees C). SOTA high density, high durability (1,500 cycles) connectors current packaging arrangements are large compared to the electronics volume. It is desirable to reduce the footprint of dense electrical signal connectors while also increasing the reliability and durability. In the SBIR Phase I effort, evaluation of novel mechanical configurations for both the connector and the contact should be accomplished, with the goal of volume reduction, high reliability, and compatibility with electronic fabrication applications. Approaches that increase the density of standard circular MIL DTL-38999, MIL DTL 5015, and related signal level (series I, II, III arrangement) connectors (1 -85 contacts) should be considered. Simulation of the major degradation mechanisms and understanding the challenges of defining test protocols should be considered.

PHASE I: Develop an advanced high density reliable connector design with reduced size and improved cyclic durability and repeatable performance over the state of the art. The technology should be applicable to both legacy and advanced configurations for harsh environments. Demonstration of the prototype technologies capability should be accomplished through simulation and basic testing. Recommend the contractor work with appropriate industry partners with expertise in connector design, material science, fabrication, and reliability testing.

PHASE II: Develop product like connector hardware components based on the Phase I prototype technologies selected. The hardware components electrical and mechanical capability will be demonstrated using appropriate test procedures for harsh environment applications. Suitability of the test procedures will be shown for the intended environments. Comparison of the technology with the state of the art will be accomplished.

PHASE III DUAL USE APPLICATIONS: In Phase III, the ability to productionize the connector hardware for new and legacy systems will be developed. Cost effectiveness of the design will be assessed, and reliability and durability will be matured for military and commercial applications. Preliminary qualification issues will be addressed and performance of the connectors will be demonstrated on a ground test engine.

#### REFERENCES:

1. Mroczkowski, Robert S., "A Perspective on Connector Reliability", Technical Presentation, 2004.
2. Turk Connectivity, "Design Considerations For Harsh Environments", White Paper, W1019, April 2017.
3. Pascucci, Vincent C., "A Brief Overview of reliability in General and for Electrical Connectors in Particular", July 1995.
4. Arrowsmith, Peter., "Surface Mount Technology Association (SMTE)", "Electrical Connector Failure Investigation."

KEYWORDS: Electrical Connectors, Reliability, Harsh Environment, Contact Tribology, MIL Connectors, High Data Rate Connections

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AF192-055 TITLE: New Concepts for High Temperature Turbine Engine Oil Pumps

TECHNOLOGY AREA(S): Air Platform

ACQUISITION PROGRAM: N/A

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct ITAR specific questions to the AF SBIR/STTR Contracting Officer, Ms. Michele Tritt, michele.tritt@us.af.mil.

**OBJECTIVE:** Develop a novel strategy to increase the usable oil temperature of turbine engine oil pumps. Concepts focus to increase the usable temperature over conventional design to a temperature of 400-500 degrees F, while maintaining cold temperature requirements, -40 degrees F. The design should accommodate both MIL-PRF-7808 and MIL-PRF-23699 oil, and allocate the option of magnetic chip detectors and sensors.

**DESCRIPTION:** Typical strategies for oil pumps will utilize oil supply pumping elements and air/oil scavenge elements. The oil pump design must also accommodate magnetic chip detectors, bypass valve and sensors. This SBIR topic seeks to explore new strategies/materials not currently utilized to increase the oil pump usable temperature to 400-500 degrees F, while maintaining a low temperature capability of -40 degrees F. A key focus would be a drop in replacement for legacy designs with significant usable temperature increase and no additional weight or complexity.

A strong collaboration with the OEMs is highly recommended from Phase II of this program.

**PHASE I:** Show the feasibility for a novel concept or new material for high temperature turbine engine oil pumps. Develop a design/test strategy for evaluating the ideas and identifying the key performance parameters necessary to document ability to perform on engine. Develop an initial transition and business plan.

**PHASE II:** The methodology developed in Phase I should be validated for additional conditions approaching those found in practice with physical testing, and show feasible build processes and stable quality assurance processes. In the Phase II effort, steps should be taken to establish requirements for integration of the high temperature oil pump design into a standalone design tool that incorporates sufficient details to allow it to successfully predict increased performance. The work should be transitioned to interested OEMs.

**PHASE III DUAL USE APPLICATIONS:** Future Phase III efforts should involve further commercialization of strategies developed for incorporation into elevated TRL demonstrations. These TRL demonstrations should focus on turbine engine lubrication system integration. Potential military application in NGAP, and a potential commercial application is the Boom Supersonic Transport XB-1 Aircraft for the SBIR/STTR technology.

**REFERENCES:**

1. MIL-PRF-7808 Specification
2. MIL-PRF-23699 Specification
3. MIL-PRF-87100 Specification (Cancelled, but may be of some help).

**KEYWORDS:** oil pump, scaling, retrofitting, MIL-PRF-7808, MIL-PRF-23699, durability, testing, analysis

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AF192-056            **TITLE:** Low Cost Mission Enabling Cold Start for Small Engines

**TECHNOLOGY AREA(S):** Air Platform

## ACQUISITION PROGRAM: N/A

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

**OBJECTIVE:** Develop and demonstrate a low cost high altitude cold start ignition system for expendable small gas turbine engines.

**DESCRIPTION:** The ignition environment of a gas turbine during high altitude (10,000 ft. to 35,000 ft.) air drop missions is very challenging. At the point of the drop, the pressure, temperature, and air mass flow are all low, and the entire gas turbine and fuel system are cold soaked to atmospheric temperatures (cold start). The ignition system has to light the combustor and spool up the engine to a self-sustaining condition over a finite period of time. For a given gas turbine and ignition system the resulting startup envelope is limited by Mach number, altitude, and environmental conditions as well as time from start of ignition to self-sustaining operation. Small engines are more challenging to ignite due to the constraints on the combustor design, primarily the high surface to volume ratio and low fuel flow injectors.

The most common system utilized today is expensive pyrotechnic start cartridges. They result in fast spool up times and reliable high altitude starting with a wide startup envelop, but are expensive relative to the cost of the entire gas turbine and introduce handling, fragility, and aging issues. As the gas turbine decreases in size the percentage cost of the pyrotechnic start cartridge grows, representing almost 1/3rd of the entire cost of the system at the smallest scales. Commonly used lower power ignition systems, such as spark ignitors or glow plugs, have restrictive startup flight envelopes and long spool up times. This is very mission limiting due to the need for dive-to-start/climb to cruise mission profiles resulting in significant inefficiencies and longer times to target. It also decreases the survivability of the ordnance.

Novel ignition approaches for the high altitude wing drop application are sought that result in a wide startup envelop, with a reasonable spool up time, and with reduced costs compared to existing approaches. Due to the nature of the mission, low cost is the most important attribute. The new approach must also be compatible with existing carriage resources and still meet the all operational requirements of the mission, such as carriage/launch loads of the system, thermal cycling, and long term storage.

**PHASE I:** Create a preliminary design and show the feasibility of the novel ignition approach to achieve a wide startup envelop for a small engine in the air drop application. An initial estimate of the system's weight, volume, viability to meet operational requirements, and the scalability of the approach should be included. Additionally, special attention should be made to estimate the resulting systems cost compared to current ignition approaches.

**PHASE II:** Design, build, and test a prototype of the ignition approach developed in Phase I for a specific small gas turbine system in both a laboratory setting and in the gas turbine. It is recommended that collaboration with either a turbine engine manufacturer or a Government lab to perform the ignition test in the gas turbine. A vision system design should also be developed during Phase II. A refined estimate of the system cost and performance parameters should be made based on the vision system design.

**PHASE III DUAL USE APPLICATIONS:** Develop a vision system level design for a specific existing expendable small gas turbine engine. Demonstrate/assess the startup envelop, spool up time, and projected final system cost.

**REFERENCES:**

1. "Comparative Analysis of Gas Turbine Engine Starting", A. Beyene and T. Fredlund, American Society of Mechanical Engineers, 98-GT-419, (1998).
2. "Gas Turbine Performance", P.P. Walsh and P. Fletcher, Chapter 9, Second Edition, Blackwell Science Ltd, Oxford UK (2004).
3. "Experimental Investigations into High-Altitude Relight of a Gas Turbine", R.W. Read, Doctoral Thesis (2008).
4. "Research on Windmill Starting Characteristics of MTE-D Micro Turbine Engine", Chen Xia, Xin Fu, Zhaoyun Wan, Guoping Huang, and Jie Chen, Chinese Journal of Aeronautics, Volume 26, Issue 4, Pages 858-867 (2013).

KEYWORDS: low cost, high altitude, cold, start, ignition, expendable, small gas turbine engine

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AF192-057 TITLE: Dynamic, Risk-Based, Situational Awareness and Response

TECHNOLOGY AREA(S): Information Systems

ACQUISITION PROGRAM: N/A

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OBJECTIVE: Develop a system for integrated threat detection, classification, and situational awareness considering data associated with risk relative to assets, providing capability for fixed and mobile asset security leveraging all available information.

DESCRIPTION: The USAF is tasked with securing both fixed-site facilities and mobile assets against a multiplicity of potential threats, including conventional weapons (rockets, artillery, mortars (RAM)), and shorter-range weapons (small arms, rocket-propelled grenades (RPGs)). Enemy use of vehicle-borne explosive devices and other improvised weapons are also of great concern. An emerging threat to site security is the rapid proliferation of low-cost UAS ("drones"). Weaponized drones, particularly operating in coordinated swarms, pose an immediate risk. Their low cost and commercial availability have enabled an increasingly deadly role in theater. Other threats include cyber-directed attacks against such infrastructure as the power grid or water supply. In some location, biological weapons, severe weather, wildfires, civil unrest, and many others threats can also pose significant operational hazards to secured facilities.

Commanders are tasked with continually assessing these threats versus the risk associated with particular defended assets. This creates a feedback loop: assess the threat, evaluate the risk relative to affected asset(s), command the optimal response. Decision makers develop risk metrics—a product of the asset's determined operational value, potential threats to that asset, and an assessment of its vulnerability. In reality, risk assessments continuously change, especially in light of detection and classification of threats constituting hostile intent.

Presently, the nature of gathering and synthesizing data from a variety of sensor systems, each with its particular



operating characteristics, requires operators to understand multiple disparate data streams from various systems. Under attack, interpreting these data streams requires an understanding of the “quirks” and characteristics inherent in each system. Decision making under such circumstances, especially if infused with incorrect and/or otherwise inaccurate information, may be suboptimal and thus prone to error.

This project seeks to improve command responses by considering event detection data from multiple networks, paired with historical data, to update asset risk metrics in real time. Machine learning algorithms can be developed to aggregate these data and weigh relevant factors. In graphical terms, this can be visualized as a situational awareness display on which threat events are continually overlaid with an updating assessment of asset risk. This information can serve as an “automated playbook” on how best to respond to certain threats, and provide valuable insight to commanders and first responders faced with dispatching countermeasures in highly dynamic, and sometimes uncertain, tactical situations. This will enable faster response to attacks, and allow countermeasures to be directed more effectively. Overall, the payoff is better use of available USAF resources, and decreased logistical burden.

This topic envisions utilization of emerging technologies in the realm of machine learning. Such systems are capable of improving their predictive accuracy (assessment of “truth”) as they are provided with more and more data. In the past few years, computational hardware required to utilize these tools has advanced to the point where such systems can be deployed in tactical command centers with minimal additional facilities requirements. Some of these systems utilize graphics processors (GPUs), which have been in wide circulation for about a decade. Additionally, new types of processor architectures are being developed specifically for deep learning frameworks. Coinciding with the advances in hardware, software tools are available that make development of applications readily accessible.

**PHASE I:** It will demonstrate the feasibility of an automated agent for situational awareness based on real-time determination of threat. Range and domain of threats and type of assets selected for assessment can be negotiated to pare the problem to a manageable level. Existing software systems may be utilized as needed. Final exam is a system simulation demonstrating one or more example scenarios.

**PHASE II:** Deliver self-contained system capable of the objectives in a supervised setting integrated at a level suitable for demonstration. Implement algorithms based on historical and live data from three or more diverse sensors, at least one being from a mobile platform. The offeror shall attempt to quantify deviations in observed performance from that predicted in system simulations in Phase I. Deliverables shall include a functional real-time processor to be used in future testing and development.

**PHASE III DUAL USE APPLICATIONS:** The system shall be further developed and improved based on results of earlier phases resulting in integrated tools ready for commercialization and transition to operational programs. This technology will provide a new and improved capability for First Responder centers in DoD, DHS, FAA, etc.

#### REFERENCES:

1. Girão P.S., Postolache O., Pereira J.M.D. (2009) Data Fusion, Decision-Making, and Risk Analysis: Mathematical Tools and Techniques. In: Pavese F., Forbes A. (eds) Data Modeling for Metrology and Testing in Measurement Science. Modeling and Simulation in Science, Engineering and Technology. Birkhäuser Boston.
2. D.L. Hall and J. Llinas (Editors). Handbook of Multisensor Data Fusion. The Electrical Engineering and Applied Signal Processing Series, CRC Press LLC, Boca Raton (FL), 2001.
3. Stampouli, D & Vincen, Daniel & Powell, Gavin. (2009). Situation assessment for a centralized intelligence fusion framework for emergency services. 2009 12th International Conference on Information Fusion, FUSION 2009. 179–186.
4. <https://developer.nvidia.com/deep-learning>

**KEYWORDS:** artificial intelligence, big data, Data Analytics, data fusion, machine learning, risk analysis

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AF192-058 TITLE: Delivery System and Compatible Chemicals for Rapid Collapse of Hi-EX Foam

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Environmentally benign material that rapidly collapses foam, is non-injurious to military assets or personnel, and cleans up with foam after a release event; delivery system for said composition must integrate with the hi-EX foam sprayer system.

DESCRIPTION: Accidental Hi-EX foam releases in hangars have killed and injured personnel. In 2014 an accidental release of foam killed two contractors at Eglin AFB, FL. Hi-EX foam is necessary to put out hangar fires, as there is no practicable substitute currently on the market to replace it for hydrocarbon fires. Therefore, there is need for a technology that rapidly (20 or more feet of foam within 3 minutes) collapses the foam without damaging military assets or poisoning personnel, is environmentally friendly (i.e. biodegradable, non-persistent in the environment, and non-toxic) and is easy to clean up. The current state-of-the-art is to spray the foam with water to dissipate it, or waiting for the foam to break down on its own. Each is unacceptably slow.

The delivery system for this material must be compatible with current technology. Hi-Ex foam is generated in specialized systems that are so deployed as to evenly cover the hangar with foam when deployed. The delivery system of the chemical should 1) also evenly cover the hangar, to evenly collapse the foam when deployed, and 2) not interfere with the working of the Hi-Ex foam system or other hangar systems.

PHASE I: Sample of material that collapses a column of Hi-EX foam at mean rate NLT 6 ft/min. Apply agent to Hi-EX foam from bench-scale prototype delivery system. For any component not known to be environmentally benign, offeror shall provide lab data (e.g., LD50, IC25, BOD, COD, environmental persistence and breakdown products, etc) identifying potential environmental impact of material. Corrosivity or other degradation of typical hangar material or staff is unacceptable.

PHASE II: Assemble and demonstrate a full-size prototype delivery system in a hangar-sized area at Tyndall AFB. Collapse 20 ft of Hi-EX foam in a volume the size of an F-35 hangar in three minutes or less. The foam and chemical remnants should be no more difficult to clean up than a spontaneously collapsed foam

PHASE III DUAL USE APPLICATIONS: Market Final product to civil and private aviation for aircraft hangar fire suppression, flammable storage facilities, and emergency management areas.

#### REFERENCES:

1. Weaver, R. "Commander Directed Investigation Findings and Conclusions Concerning Eglin AFB Accidental High Expansion Foam Discharge and Fatality," Eglin Air Force Base, Florida (undated.)
2. NFPA 409, Standard on Aircraft Hangars
3. NFPA 11 A, Standard for Medium- and High-Expansion Foam Systems

KEYWORDS: Hi-Ex Foam, High Expansion Foam, Hangar, Aircraft

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AF192-059

TITLE: Unmanned Aerial System (UAS) Aircraft Rescue and Firefighting (ARFF)

TECHNOLOGY AREA(S): Information Systems

ACQUISITION PROGRAM: N/A

OBJECTIVE: An autonomous system to identify, assess, respond to, and suppress or extinguish an aircraft fire within 10 miles of the stationed unit and conduct rescue.

DESCRIPTION: Unmanned and autonomous systems technology has burgeoned for more than a decade, outpacing methods to apply the capabilities to applicable problems. Technology is sought that autonomously gathers and processes information from various sources and sensors to identify an aircraft fire, communicate with other aircraft traffic and initially respond to an aircraft fire autonomously. During an event, the system will notify emergency services, deploy and using the Unmanned Aircraft System Traffic Management System (UTM) or similar system navigate through military and civilian airspace to an aircraft fire while carrying the means to suppress or extinguish a 50-MW fire and conduct a basic rescue mission on conscious personnel. The minimum payload the system should be able to carry is 1 metric ton to successfully perform the firefighting and rescue mission.

Relevant state-of-the-art robotic firefighting technology ranges from tethered drones to heavy lift semi-autonomous aircraft. Solutions are sought that provide a semi-autonomous, non-tethered response to aircraft fire events in the vicinity of airbases and airfields. The solution should be able to operate close to a 50-MW fire without degradation. The system should be able to stay on station for the minimum estimated response time of the local emergency services. A highly desirable feature would be ability to map the trajectory of an aircraft making a mayday call to estimate point and time of impact, to allow an extinguishment response before the fire has developed. The same constraints on toxicity, environmental persistence, etc. apply as to AFFF replacements.

PHASE I: Use small-scale, virtual or modeling & simulation testing & evaluation to identify possible solutions and develop initial software for fire and emergency identification and communication with emergency services. Demonstrate detection & control functions with a small drone. Justify the choice of extinguishant.

PHASE II: Assemble a prototype system for field demonstration in a relevant operating environment selected with service input. After the demo deliver the system to the Government for end-user evaluation. The prototype must autonomously deploy and navigate to an aircraft fire while communicating relevant information to aircraft control systems.

PHASE III DUAL USE APPLICATIONS: Final product will find a market in civilian and private aviation, firefighting and emergency management areas.

REFERENCES:

1. FAA Circular 150/5200-31C- Airport Emergency Plan (Consolidated AC includes Change 2) June 19, 2009
2. NFPA 403 Standard for Aircraft Rescue and Fire-Fighting Services at Airports, 2018
3. Stalker and K-MAX talk to air traffic control to safely operate while detecting and dousing fires, 7 DEC 2015, <https://spectrum.ieee.org/automaton/robotics/drones/lockheeds-drones-fires>

KEYWORDS: Aircraft Rescue and Firefighting (ARFF), autonomous, drone, extraction

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AF192-060

TITLE: A small multi-spectral Imagery Pod to Provide High Resolution Rangeland Management Data

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: --

OBJECTIVE: Develop a small multi-spectral imagery pod, to hang under a drone or attached to a rover, capable of providing data to show high resolution vegetation health and distribution, soil properties, soil density, moisture content, etc. to include the “biological soil crust” to assist in restoration efforts and collect data required to comply with the Endangered Species Act (ESA) and the Sikes Act, that would otherwise require “boots on the ground”.

DESCRIPTION: Vegetation health is a determinate parameter in the management of wildlife. This effort will address the relative health of vegetation to include the “biological soil crust” and provide data for management activities (e.g. recovery and revegetation). Plants appear green because chlorophyll in the leaves absorbs much of the incident light in the visible wavelengths, particularly the blue and red, while the green color is reflected. Therefore, light reflected by the leaves depends on the amount and various types of leaf pigments that can be used to predict relative health. For example, a water-stressed leaf is known to have low reflectance in the nonvisible wavelengths from about 750 to 1100 nm. Measuring the difference in reflected light at various wavelengths of the electro-magnetic spectrum also makes it possible to distinguish vegetation from soil, green and senescent vegetation, and vegetation species. There has, however, been limited to no application of this technique to rangeland management or to the microbiotic crusts management. Multi-spectral imagery has been widely used to assess crop condition, cover, and growth. Different crop characteristic can be determined based on the band combinations used and include chlorophyll content, biomass and water stress. Hyperspectral imaging is also being used in the detection and diagnostics of disease, nutrient deficiencies, weeds and pests in crop fields. Soil crusts are formed by living organisms and their by-products, creating a surface crust of soil particles bound together by organic materials. Aboveground crust thickness can reach up to 10 cm. The general appearance of the crusts in terms of color, surface topography, and surficial coverage varies. Soil crusts play an important role in the environment. Because they are concentrated in the top 1 to 4 mm of soil, they primarily effect processes that occur at the land surface or soil-air interface. These include soil stability and erosion, atmospheric nitrogen-fixation, nutrient contributions to plants, soil-plant-water relations, infiltration, seedling germination, and plant growth. Crusts are well adapted to severe growing conditions, but poorly adapted to disturbances. Domestic livestock grazing, and more recently, recreational activities and military activities place a heavy toll on the integrity of the crusts. Disruption of the crusts brings decreased organism diversity, soil nutrients, stability, and organic matter. Fire is a common occurrence in many regions where microbiotic crusts grow. Investigations show that fires can cause severe damage, but that recovery is possible. Low-intensity fires do not remove all of the crust structure, which allows for regrowth without significant soil loss. Shrub presence increases the intensity of the fire, decreasing the likelihood of early vegetative or crust recovery. Full recovery of crust from disturbance is a slow process, particularly for mosses and lichens. There are, however, means to facilitate recovery if the location of viable communities can be determined. The proposed technology should be man portable, attached to a rover or drone. The system cannot rely on grid transmitters or receivers and must be appropriate for use in federally designated critical habitat. This is not a request for a drone or rover development. The sensor pod should be self-contained and of a size suitable for use on a drone or rover.

PHASE I: Research in this phase should focus on device stability in rough terrain to prevent device tip over, bandwidth constraints for operation of the vehicle and camera resolution, battery life/recharging- current batteries require fairly frequent recharging and the method of delivering electricity to the vehicle – i.e. prove of concept.

PHASE II: It should be focused on system design, manufacturing, environmental maintenance, and quantification of system performance of a pre-production prototype. From the applied research and conceptual design in Phase I, develop a working, scaled- up prototype system. Evaluate if the system can determine the health of vegetation and soil crusts.

PHASE III DUAL USE APPLICATIONS: Military Application: Military bases are required by the Sikes Act to manage the wildlife on their bases. Historically, this data has been collected by “boots on the ground” biologist. Field biologist are expensive and sometime difficult to find to provide the data need to comply with the various federal wildlife related laws (ESA, Sikes Act, etc.). Commercial Application: All federal and state agencies that manage land are required by various laws and regulations to manage the wildlife on their land. As on military land, this data has been historically collected by “boots on the ground” biologist. With reduce budgets and limited

manpower these agencies must still comply with the various federal wildlife related laws

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3. Jacobi J, Kühbauch W (2005) Site-specific identification of fungal infection and nitrogen deficiency in wheat crop using remote sensing. In: *Proceedings of the 5th European Conference on Precision Agriculture*, edited by J.V. Stafford (Wageningen Academic Publishers, Netherlands), 73–80

KEYWORDS: Vegetation Health, Multi-Spectral Imagery, Sensor, Detection, Critical Habitat, Federally Threatened Species

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AF192-061 TITLE: Energy Storage/Real-Time Peak Shaving

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: N/A

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

OBJECTIVE: Develop a real-time peak shaving, energy storage technology that can be installed at an AF sustainment complex / industrial facility.

DESCRIPTION: Because electricity pricing is tied to usage, power consumption during peak times costs considerably more than power purchased during off-peak time. The focus of this effort is to develop cost-efficient energy storage solutions. Storage would be filled with off-peak power (or potentially alternative power) and fed back into the system during peak usage. The solution would also require real time usage monitoring system in order to predict when to charge and when to discharge.

Determine acceptable locations and size for energy storage integration within the installation's electric distribution system. This effort will be coordinated with a utility privatization contractor - privately owned power management company (City Light and Power (CLP)) and the base Civil Engineering. CLP maintains and operates the military installation's transmission and distribution systems.

The main base power at Hill reaches peak demand around 45 megawatts (MW). Peak demand during summer months usually occurs between 1 p.m. and 2 p.m. Monday through Thursday. Rocky Mountain Power (RMP) supplies electricity to Hill under rate schedule 9. During summer months, RMP Rate 9 on-peak hours begin at 1 p.m. and end at 9 p.m., Monday through Friday. Summer peak power charge is \$13.96/kW and there is no power charge for off peak hours. Winter on peak hours begin at 7 a.m. and end at 11 p.m., Monday through Friday. Winter

peak demand usually occurs around the 10 a.m. hour Monday through Thursday, peak charges are \$9.47/kW with no power charge for off peak hours.

RMP supplies power at 46 kV to HAFB. Power is supplied to substation 5 from the south side of the base through the Syracuse substation switch (SSS) located near the Fam Camp within the base fence line. 46 kV power is stepped down to 12,470 V at substations 2, 3, 4 and 5. Backup feed is at substation 2 during SSS interruption. Service to substation 2 is fed from the RMP Riverdale substation. Substation 2 is located on the north side of the base, 10 miles away from substation 5.

The SSS switch serves as the line of demarcation between RMP and CLP distribution assets. Time meter data can be obtained at the SSS, current meter data is delivered to HAFB by RMP with a 24 hr delay. Real time metering of 1 to 15 min. could be sent to the base advanced metering reading system (AMRS) if appropriate cyber security authorization is obtained. Integrating with AMRS would allow user interface with the meter data.

The system shall determine when power should be applied to or drawn from the storage device. This effort shall shave the peak load demand for power from the utility company. R&D controls shall ensure safe energy discharge into and off of the transmission system. At a minimum the system shall provide 1MW to 2 MW of peak shaving – greater values will be considered. The R&D shall optimize the energy storage, charge and discharge rates. The algorithm for energy discharge shall be based on demand profile, rate 9 on-peak schedule and real time data acquisition. The contractor shall develop the appropriate power metering, data acquisition and communication infrastructure.

The contractor shall determine the best energy storage technology option (could be combination of energy storage techniques) for the AF sustainment installation.

**PHASE I:** R&D solution that meets the above requirements and conduct preliminary business case analysis (BCA) to determine implementation costs, including a return-on-investment (ROI) calculation that compares anticipated savings to expected costs. Proof-of-concept prototype(s) shall be developed to demonstrate conformance to the requirements.

**PHASE II:** Initiate and complete the test plan developed in Phase I. Proof-of-concept prototype(s) shall be refined to installation-ready article and shall undergo testing to verify and validate all requirements. This process may require multiple iterations before a final design is selected. Refine BCA/ROI based on the final design.

**PHASE III DUAL USE APPLICATIONS:** If developed technologies are cost effective, passes verification / validation and qualification testing, then it shall proceed to transitioning and implementation of the technologies. With possible application to other AFSC sites.

#### REFERENCES:

1. Department of Defense 2016 Operational Energy Strategy
2. Department of Defense Energy Manager's Handbook, Aug 5 2005
3. Department of Defense Directive Number 4180.01 16 Apr, 2014
4. Air Force Policy Directive (AFPD) 90-17, Energy and Water Management, 18 Nov 2016

**KEYWORDS:** Facility Power, Peak Shavings, Energy Storage, Electric Power

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AF192-062 TITLE: Determination of Significant Failure Size for Finite Element Analysis (FEA)

**TECHNOLOGY AREA(S):** Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Determine threshold of finite element analysis “hot spot” characteristics where real-world degradation or failure effects become predictable and measureable.

DESCRIPTION: Hill AFB Landing Gear (LG) office uses Finite Element Analysis (FEA) to predict LG part failures. Analyses will often reveal localized stress concentrations or “hot spots” where a limited number of elements are indicated by the software as exceeding material limits. Currently, determination as to when the hot spots would result in real-world part failure is based on the size of the area of elements stressed above yield or ultimate strength. This determination is subjectively based on the experience of the LG engineer performing the FEA, and can differ between engineers even for the same component in the same situation. For example, some have used the criteria in industry boiler and pressure vessel standard ASME BPVC Section VIII-2 to make this determination for LG hardware.

The research and development effort shall produce a predictive relationship between FEA stress concentration characteristics and real-world hardware effects under the same loading conditions. Relevant characteristics of FEA hot spots may include but are not limited to mesh or part geometry, size, stress levels, location, distance between stress concentrations, and sensitivity to existing part defects/damage. Loading scenarios may include tension, compression, shear, and bending. Common LG part materials include Aluminum 7075-T73 and 7050-T73, Steel 300M and 4340. Alternative finite element software/meshing/analysis methods other than what Hill AFB currently uses are within scope of this study. The model predictions shall be verified and validated on physical test specimens according to ASTM E8 for tension. The contractor shall publish a commercial standard or specification for interpreting FEA stress concentrations based on the results of this effort.

PHASE I: R&D solution that meets the above requirements and conduct preliminary business case analysis (BCA) to determine implementation costs, including a return-on-investment (ROI) calculation that compares anticipated savings to expected costs. Proof-of-concept prototype(s) shall be developed to demonstrate conformance to the requirements.

PHASE II: Initiate and complete the test plan developed in Phase I. Proof-of-concept prototype(s) shall be refined to installation-ready article and shall undergo testing to verify and validate all requirements. This process may require multiple iterations before a final design is selected. Refine BCA/ROI based on the final design.

PHASE III DUAL USE APPLICATIONS: If developed technologies are cost effective, passes verification / validation and qualification testing, then it shall proceed to transitioning and implementation of the technologies. With possible application to other AFSC sites.

REFERENCES:

1. ASME/BPVC sec VIII-2 "Boiler and Pressure Vessel Code (BPVC)"
2. ASTM E 8 "Standard Test Methods for Tension Testing of Metallic Materials"
3. “The Theory of Material Failure” By Richard M Christensen ISBN # (978-0-19-966211-1)

KEYWORDS: Finite Element Analysis, FEA, Hotspots, Landing Gear

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AF192-063 TITLE: Ergonomic Dead Man Switch on Blast Nozzles

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: R&D an ergonomic dead man switch design for use with Hill AFB PMB equipment

DESCRIPTION: Abrasive blast operators within 576 PSS need an ergonomic replacement for the blast activation dead man switch currently used on plastic media blast (PMB) nozzles for paint removal on F-16, C-130, and A-10 aircraft. Currently, PMB operators activate hoses by squeezing a large dead-man switch affixed to the PMB nozzle. The grip forces required to initiate and maintain trigger activation are 16-lbf and 8-lbf, respectively. Pre-activation and activation tangential grip distances are 3.75-in and 3-in, respectively. PMB operators can be expected to hold these trigger grips in activated position for up to four hours per shift. Due to the poor ergonomic qualities of the current switch, 576 PSS operators experience abnormally high rates of chronic shoulder injuries and carpal-tunnel syndrome (CTS) corrective surgeries costing the Air Force an estimated \$340,000 per year in workman's compensation, operator time off-work, or alternate work assignments.

The replacement design must meet OSHA dead man switch requirements and reduce or eliminate the fatigue and injuries associated with the current switches. The design shall meet performance, interface, and form-factor requirements of 576 PSS's PMB systems. To reduce the risk of CTS and shoulder injuries, the design shall meet or exceed requirements in OSHA Standard 1910.244(b) and its two accompanying interpretations, and MIL-STD-1472G. The maximum allowable activation and maintaining grip pressures shall be 5-lbf and 3-lbf respectively. The design shall be adjustable, to provide ergonomic benefit regardless of the individual operator using it, and shall not exceed 12 oz. in weight. The design shall be equally useable by operators lying prone in F-16 intakes and by users standing up straight. Maximum switch deactivation time shall be 0.3 seconds. The switch shall be designed to mitigate risks to the aircraft being worked on, primarily that of contact damage. The switch shall survive 100 repeated 48-in vertical drops onto concrete in its operational configuration and remain functional for at least 500 hours of cumulative use. The design shall be resistant to un-commanded activation through drops, bumps, or electromagnetic interference (EMI). The design, when engaged and allowing flow of media, shall reliably disengage in 0.5-sec or less to de-activate media flow in user-unconscious, nozzle-drop, and other physical failure scenarios. The design shall interface with 576 PSS's pneumatically controlled PMB systems, and shall be able to be exchanged from the blasting hose in under 6 minutes using common tools. The design must be self-contained (i.e. no interface to systems other than the user and PMB system), and shall not interfere with the operator's personal protective equipment (PPE), stands, or equipment. The allowable physical envelope for the design is within 5 inches radially from the blast hose, with at least 2 inches of clearance from the opening of the blast nozzle, and length not to exceed 8 inches. The design shall meet or exceed OSHA requirements for equipment used in Class II Division 1 locations.

PHASE I: R&D solution that meets the above requirements and conduct preliminary business case analysis (BCA) to determine implementation costs, including a return-on-investment (ROI) calculation that compares anticipated savings to expected costs. Proof-of-concept prototype(s) shall be developed to demonstrate conformance to the requirements.

PHASE II: Initiate and complete the test plan developed in Phase I. Proof-of-concept prototype(s) shall be refined to installation-ready article and shall undergo testing to verify and validate all requirements. This process may require multiple iterations before a final design is selected. Refine BCA/ROI based on the final design.

PHASE III DUAL USE APPLICATIONS: If developed technologies are cost effective, passes verification / validation and qualification testing, then it shall proceed to transitioning and implementation of the technologies. With possible application to other AFSC sites.

#### REFERENCES:

1. OSHA Standard 1910.244(b) – Occupational Safety and Health Standards
2. MIL-STD-1472G – Human Engineering
3. OSHA Standard 1926.449 – Safety and Health Regulations for Construction

KEYWORDS: Ergonomic, Bead Blast, Fatigue, Safety, Carpal Tunnel, Chronic Shoulder Injuries, Trigger Grip

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AF192-064 TITLE: MIL-PRF-85285 Capable “Controlled-Spray” Head for Automated Stenciling of Aircraft Markings

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: N/A

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

OBJECTIVE: Develop a MIL-PRF-85285 topcoat capable, high accuracy spray head to allow for the implementation of robotic stenciling/painting capabilities of aircraft markings.

DESCRIPTION: Repaired aircraft parts must be repainted prior to reinstallation, and marked in accordance with T.O. 1-1-8, per AFMCI 21-117. The 402nd CMXG at Robins AFB currently utilizes robotic technologies in their repainting processes. However, the application of markings using stencils continues to be conducted by hand as the spray head used to paint large areas are not capable of fine, high accuracy swaths. An opportunity exists to automate the application of aircraft markings, creating a robust, efficient process absent of reiteration due to human error. Currently, technology exists allowing for the automated painting and marking of aircraft parts using patented hardware and software for “large -scale robotic inkjet printing on aircraft and other complex surfaces”<sup>1</sup>. Southwest Research Institute (SwRI) was awarded a patent for “High Accuracy Inkjet Printing,” in which ink is “printed” onto complex surfaces, such as aircraft parts, with high precision. However, the ink utilized in this process is not equivalent to the MIL-PRF-85285 topcoat required for aircraft markings in accordance with T.O. 1-1-8, per AFMCI 21-117. Furthermore, the hardware is not capable of spraying the more viscous MIL-PRF-85285 topcoat. The proposed research would consider the existing “Inkjet Printing” technology to design and develop a high accuracy, controlled-spray paint head capable of the “precise application of multiple graphic swaths of color MIL-PRF-85285 topcoat onto complex surfaces, creating a contiguous graphic image”<sup>2</sup>. The development of high accuracy topcoat “printing” will alleviate discontinues, spaces, gaps, and other human errors that result in the need for reiteration on an already time consuming process. Additionally, the development of such capabilities will expedite the painting and marking process, removing it as a bottleneck of the repair and reinstallation procedures.

PHASE I: Develop a proof of concept high accuracy “Paint Jet” prototype. In this phase, the process will demonstrate ability to produce a controlled spray of MIL-PRF-85285 topcoat. Precise application, or “Printing”, of multiple swaths of color topcoat may be limited to flat surfaces in a single direction of movement. The prototyping in this phase will provide key input to developing the capability to create a contiguous encoded pattern over complex surfaces.

PHASE II: Develop the high accuracy “Paint Jet” to a deployment ready state. Greater ability to “print” MIL-PRF-85285 topcoat over complex surfaces will be implemented. The “Paint Jet” head will be fit to the 402nd CMXG’s robots, and timed with their system to ensure the accurate and precise application of multiple swaths of color paint creating contiguous graphic images. The goal of the phase II will be working robotic stencil/marking capabilities resulting in measurable improvements in the processing time of repainting and marking repaired aircraft parts.

PHASE III DUAL USE APPLICATIONS: A successful system could be marketed to other defense customers who require the ability to quickly apply markings using high resilience paint, such as MIL-PRF-85285 topcoat.

REFERENCES:

1. Evans, Paul. "Blazing a Trail for Smarter, More Agile Automation", Industry Today, Vol. 20, Issue 1, March 2017.
2. "Patented SwRI Inkjet System Can Literally Ink a Jet", Southwest Research Institute, <https://www.swri.org/press-release/patented-swri-inkjet-system-can-literally-ink-jet>, 28 February 2017.
3. "Corrosion Control and Prevention Program and Marking of Aerospace Equipment", Air Force Materiel Command Instruction 21-117, [http://static.e-publishing.af.mil/production/1/afmc/publication/afmci\\_21-117/afmci21-117.pdf](http://static.e-publishing.af.mil/production/1/afmc/publication/afmci_21-117/afmci21-117.pdf), 28 May 2014.
4. "Application and Removal of Organic Coatings, Aerospace and non-Aerospace Equipment", Technical Manual: TO 1-1-8, [http://www.robins.af.mil/Portals/59/document s/technicalorders/1-1-8.pdf?ver=2016-07-29-154634-250](http://www.robins.af.mil/Portals/59/document%20s/technicalorders/1-1-8.pdf?ver=2016-07-29-154634-250), 24 August 2017.

KEYWORDS: Stencil, automated, spray

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AF192-065 TITLE: High Precision, Non-Line-of-Sight Point Cloud Generation

TECHNOLOGY AREA(S): Materials/Processes

ACQUISITION PROGRAM: N/A

OBJECTIVE: Research and develop a technology capable of generating high precision point cloud scans of intricate parts with multiple internal services that are not accessible for traditional laser scanning or other line-of-sight techniques.

DESCRIPTION: Many gun systems in armament require intricate castings of aluminum or steel parts with multiple internal surfaces that are very difficult to inspect with traditional means and impossible to inspect with line of sight surface scanning such as laser scanning. This makes it extremely difficult and time consuming to inspect these parts during first article testing or production lot testing which adds to lead time and risk associated with procurement. It also makes government testing of failed parts nearly impossible because of the lack of specialized tooling and fixtures to hold/check the parts.

A technology is being sought that has the ability to look through the part (similar to an X-ray) and generate a very precise point cloud or surface model of the part. This point cloud or model must be accurate down to 0.0001-inch objective, 0.0005-inch threshold for the entire part. The technology must be capable of working through any steel or aluminum with a wall thickness of approximately 0.5 inches. The operation should be as automated as possible and require very little user training. The bounding box for most parts is 18 in. x 18 in. x 18 in. or less, though some parts would require a larger capacity of approximately 24 in. x 24 in. x 36 in.

Current scanning inspection techniques are limited to surface laser scans. There are some rudimentary X-ray inspection techniques, but these are mostly limited to visualization and flaw detection. There is currently no technology that can measure, visualize, and display non-line-of-sight dimensions, though it may be possible to marry current line-of-sight scanning with X-ray or other non-destructive inspection techniques.

PHASE I: Demonstrate hidden surface scan feasibility and develop a complete a demonstration of concept for accurately measuring non-line-of-sight dimensions.

PHASE II: Demonstrate a full scan of a moderately complex casting up to 18 in. x 18 in. x18 in., with internal dimensions accurately measured, tolerance, and displayed.

PHASE III DUAL USE APPLICATIONS: Demonstrate a full scan of a complex casting up to 18 in. x 18 in. x18 in., with internal dimensions accurately measured, tolerance, and displayed.

#### REFERENCES:

1. J.E. Goodman, J.O'Rourke, editors \Handbook of discrete and computational geometry," CRC Press LLC, Boca Raton, FL; Second Edition, April 2004.
2. S. Sachs, S. Rajko, S.M. LaValle \Visibility based pursuit-evasion in an unknown planar environment," to appear in International Journal of Robotics Research, (2003).
3. Validation of a Non-Line-of-Sight Path-Loss Model for V2V Communications at Street Intersections, Abbas, Taimoor; Thiel, Andreas; Zemen, Thomas; F. Mecklenbräuer, Christoph; Tufvesson, Fredrik

KEYWORDS: point cloud, non-line-of-sight dimensions

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AF192-066 TITLE: All-electronic Switch Exceeding 10 THz

TECHNOLOGY AREA(S): Sensors

ACQUISITION PROGRAM: AEHF - Advanced Extremely High Frequency (AEHR) Satellite Program

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

OBJECTIVE: Develop a robust, solid-state, scalable all-electronic switching and broadband amplification technology that operates in the >10 THz regime at  $10^{+6}$  A/cm<sup>2</sup> current densities with a 1W output power.

DESCRIPTION: An electronic technology platform for the broadband amplification of currents at speeds up to 30 THz with ideally symmetric on-off characteristics and sufficient power of 1 W is needed. High frequency, high power amplifiers are currently bottlenecks for many technologies including satellite communications, remote sensing and threat detection, or electronic warfare [1], but especially for radar such as on combat aircraft [2]and ultra-high frequency telecommunications with extreme bandwidth in the atmospheric attenuation window [3, 4] around 30 THz. For such applications, additional requirements for this technology include stability over a very wide operating temperature range. This topic calls for new solid-state device architectures based on new materials because of the limitations of existing technologies. All practical broadband amplifiers that operate at >1 THz are based on the more than one-hundred year old principle of vacuum tubes. However, pushing vacuum electronics

significantly above THz frequencies requires significant advances in nearly all aspects, including novel ultra-high precision manufacturing, designs for ultra-high current density electron beams, new cathode materials, novel circuit designs and optics [1]. This complexity makes solid-state devices highly desirable. However, solid-state devices based on semiconductor materials are fundamentally limited in speed by the capacitance of the depletion layers inherent in all junction-based devices. The depletion layers in diodes and transistors form capacitors and the required capacitor charging and especially discharging (“off-switching”) during transistor switching limits the maximum operating frequency. Metal-insulator-metal junctions also have inherent capacitances. Besides, demonstrated power output is in the  $\mu\text{W}$  – few-mW range, and unpractical cryogenic cooling is typically required. Spin-based transistors have been previously pursued but their operating speeds are limited by the ferromagnetic resonance frequency [5]. The theoretical scaling relation  $\text{Power} \propto 1/(\text{frequency})^2$  [6] limits all technologies except for vacuum electronics to lower power than the 100 mW to 1 W needed for useful telecommunication [1]. Because of these reasons, a solid-state based broadband amplification technology is solicited with key performance parameters of 30 THz, frequency, power output of at least 1 W, and operating temperatures over a wide range, significantly above room temperature.

**PHASE I:** Develop a conceptual design of a broadband, all solid-state gain-achieving device working up to 30 THz, with at least 1 W output power, and current densities of 106 A/cm<sup>2</sup>. The development will be based on an analysis of existing materials, identify the high-risk technical elements, and initial risk reduction via testing or modeling. Demonstrate the feasibility of this fundamental approach. Narrow achievable device parameters in terms of gain frequency and power response.

**PHASE II:** Demonstrate gain in a real device. Demonstrate fanout. Build one prototype device that can achieve the specifications. Establish the device geometries and material properties that are most critical to achieve a large current gain and the frequency response. Optimize materials to maximize gain at frequencies > 10 THz.

**PHASE III DUAL USE APPLICATIONS:** Commercialize electronics switching platform. Expand the capability to meet requirements for other Air Force test facilities and mature the technology for commercialization to all DoD facilities and the private sector.

#### REFERENCES:

1. S.S. Dhillon, M.S. Vitiello, E.H. Linfield, A.G. Davies, C.H. Matthias, B. John, P. Claudio, M. Gensch, P. Weightman, G.P. Williams, E. Castro-Camus, D.R.S. Cumming, F. Simoens, I. Escorcia-Carranza, J. Grant, L. Stepan, K.-G. Makoto, K. Kuniaki, K. Martin, A.S. Charles, L.C. Tyler, H. Rupert, A.G. Markelz, Z.D. Taylor, P.W. Vincent, J.A. Zeitler, S. Juraj, M.K. Timothy, B. Ellison, S. Rea, P. Goldsmith, B.C. Ken, A. Roger, D. Pardo, P.G. Huggard, V. Krozer, S. Haymen, F. Martyn, R. Cyril, S. Alwyn, S. Andreas, N. Mira, R. Nick, C. Roland, E.C. John, B.J. Michael, The 2017 terahertz science and technology roadmap, *Journal of Physics D: Applied Physics* 50(4) (2017) 043001.
2. T. Withington, Chinese Claims of Terahertz Radar? <https://www.monch.com/mpg/news/ew-c4i-channel/3881-chinesewhispers.html>, 2018 (accessed 12/18/2018.2018).
3. G.J. Zissis, W.L. Wolfe, *The infrared handbook, Infrared Information and Analysis (IRIA) Center for the Office of Naval Research, Washington, 1978.*
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