AIR FORCE (AF)
22.1 Small Business Innovation Research (SBIR)
Phase I Proposal Submission Instructions
AMENDMENT 4
20 December 2021

The purpose of amendment is to:

1. Chart 1: Air Force 22.1 SBIR Phase I Topic Information at a Glance, Technical Volume Content column information for each topic is changed to read, “White Paper NTE XX **Pages**”. The maximum number of pages specified for each individual topic **is unchanged**.

2. Paragraph entitled “Limitations on Length of Proposal” is changed to read, “Phase I Technical Volume **page** limits as identified in Chart 1 (above) do not include the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-h). The Technical Volume must be no smaller than 10-point on standard 8-1/2" x 11" paper with one-inch margins. Only the Technical Volume and any enclosures or attachments count toward the page limit. In the interest of equity, **pages** in excess of the stated limits will not be reviewed. The documents required for upload into Volume 5, “Other”, do not count toward the specified limits”.

3. The Air Force Technical Point of Contact for Topic AF221-0008, Satellite and Debris Discrimination and Identification, from Zachary Funke to **Dr. John Gaebler, (808) 891-7771, john.gaebler.1@spaceforce.mil**.

All other content, as previously amended, remains unchanged and in full effect.

AIR FORCE (AF)
22.1 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
AMENDMENT 3
10 December 2021

The purpose of this amendment is to correct the following:

Chart 1: Air Force 22.1 SBIR Phase I Topic Information at a Glance, Topic Number AF221-0024, Max SBIR Funding, is changed from “$75,000” to “**$150,000**”.

All other content remains unchanged and in full effect.

AIR FORCE (AF)
22.1 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
AMENDMENT 2
2 December 2021

The purpose of this amendment is to correct the Air Force Technical Point of Contact for Topic AF221-0014, Cross-Compatible Electronic Kneeboard Integration, from **Chandler Panetta** to **Nicholas Soto**, **(315) 330-2441**, **nicholas.soto.8@us.af.mil**.

All other content remains unchanged and in full effect.

AIR FORCE (AF)
22.1 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
AMENDMENT 1
2 December 2021

The purpose of this amendment is to correct the following:

1. Air Force 22.1 SBIR Phase I Topic Index, page AF-7, topic number **AF213-0005**. i.e., Image-based COTS Bidirectional Reflectance Distribution Function (BRDF) Measurement, is changed to **AF221-0005**.

2. Topic **AF213-0005**, i.e., Image-based COTS Bidirectional Reflectance Distribution Function (BRDF) Measurement, page AF-18, is changed to read Topic **AF221-0005**.

All other content remains unchanged and in full effect.

AIR FORCE (AF)
22.1 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions

AF Phase I proposal submission instructions are intended to clarify the Department of Defense (DoD) Broad Agency Announcement (BAA) as it applies to the topics solicited herein. **Firms must ensure proposals meet all requirements of the 22.1 SBIR BAA posted on the DoD SBIR/STTR Innovation Portal (DSIP) at the proposal submission deadline date/time.**

Complete proposals **must** be prepared and submitted via https://www.dodsbirsttr.mil/submissions/ (DSIP) on or before the date published in the DoD 22.1 SBIR BAA. Offerors are responsible for ensuring proposals comply with the requirements in the most current version of this instruction at the proposal submission deadline date/time.

Please ensure all e-mail addresses listed in the proposal are 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. **If changes occur to the company mail or email addresses or points of contact after proposal submission, the information must be provided to the AF SBIR/STTR One Help Desk.** The message shall include the subject line, “22.1 Address Change”.

Points of Contact:

- General information related to the AF SBIR/STTR program and proposal preparation instructions, contact the AF SBIR/STTR One Help Desk at usaf.team@afsbirsttr.us.
- Questions regarding the DSIP electronic submission system, contact the DoD SBIR/STTR Help Desk at dodsbirsupport@reisystems.com.
- For technical questions about the topics during the pre-announcement and open period, please reference the DoD 22.1 SBIR BAA.
- Air Force SBIR/STTR Contracting Officers (CO):
    - Ms. Kristina Croake, kristina.croake@us.af.mil
    - Mr. James Helmick, james.helmick.2@us.af.mil

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 events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers (PTACs), http://www.aptacus.us.org. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

Chart 1: Air Force 22.1 SBIR Phase I Topic Information at a Glance

Topic Number	Performance Period	Max SBIR Funding	Technical Volume Contents
AF221-0001	9 months	$150,000	White paper NTE 5 Pages
AF221-0002	9 months	$150,000	White paper NTE 25 Pages
AF221-0003	9 months	$150,000	White paper NTE 10 Pages
AF221-0004	9 months	$50,000	White paper NTE 25 Pages
AF221-0005	9 months	$150,000	White paper NTE 10 Pages
AF221-0006	9 months	$150,000	White paper NTE 10 Pages
AF221-0007	9 months	$150,000	White paper NTE 10 Pages
AF221-0008	9 months	$150,000	White paper NTE 10 Pages
AF221-0009	9 months	$150,000	White paper NTE 10 Pages
AF221-0010	9 months	$150,000	White paper NTE 10 Pages
AF221-0011	9 months	$150,000	White paper NTE 10 Pages
AF221-0012	9 months	$150,000	White paper NTE 25 Pages
AF221-0013	9 months	$150,000	White paper NTE 25 Pages
AF221-0014	9 months	$150,000	White paper NTE 25 Pages
AF221-0015	12 months	$250,000	White paper NTE 25 Pages
AF221-0016	9 months	$150,000	White paper NTE 25 Pages
AF221-0017	8 months	$150,000	White paper NTE 25 Pages
AF221-0018	8 months	$150,000	White paper NTE 25 Pages
AF221-0019	9 months	$150,000	White paper NTE 25 Pages
AF221-0020	9 months	$150,000	White paper NTE 10 Pages
AF221-0021	9 months	$150,000	White paper NTE 25 Pages
AF221-0022	9 months	$150,000	White paper NTE 25 Pages
AF221-0023	9 months	$150,000	White paper NTE 25 Pages
AF221-0024	9 months	$150.000	White paper NTE 25 Pages
AF221-0025	9 months	$150,000	White paper NTE 10 Pages
AF221-0026	9 months	$150,000	White paper NTE 10 Pages
AF221-0027	15 months	$150,000	White paper NTE 10 Pages
AF221-0028	8 months	$100,000	White paper NTE 25 Pages
AF221-0029	9 months	$150,000	White paper NTE 25 Pages
AF221-0030	9 months	$150,000	White paper NTE 25 Pages
AF221-0031	9 months	$150,000	White paper NTE 25 Pages
AF221-0032	9 months	$150,000	White paper NTE 25 Pages
AF221-0033	9 months	$150,000	White paper NTE 25 Pages

PHASE I PROPOSAL SUBMISSION: DoD 22.1 SBIR Broad Agency Announcement, https://www.dodsbirsttr.mil/submissions/login, includes all program requirements. Phase I efforts should address the feasibility of a solution to the selected topic's requirements. For the AF, the Phase I contract periods of performance and dollar values are found in the table above.

Limitations on Length of Proposal: The Phase I Technical Volume page limits as identified in Chart 1 (above) do not include the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-h). The Technical Volume must be no smaller than 10-point on standard 8-1/2" x 11" paper with one-inch margins. Only the Technical Volume and any enclosures or attachments count toward the page limit. In the interest of equity, pages in excess of the stated limits will not be reviewed. The documents required for upload into Volume 5, "Other", do not count toward the specified limits.

Phase I Proposal Format

Proposal Cover Sheet: If selected for funding, the proposal's technical abstract and discussion of anticipated benefits will be publicly released. 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, which is completed separately. Phase I technical volume (uploaded in Volume 2) shall contain the required elements found in Chart 1. Make sure all graphics are distinguishable in black and white.

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 included
- Concise technical resumes for subcontractors and consultants, if any, are also useful.
- Identify all U.S. permanent residents to be involved in the project as direct employees, subcontractors, or consultants.
- 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. Additional information may be requested 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, if selected, and may delay contract award.

Include a work plan outline in the following format:
Scope: List the effort's major requirements and specifications.
Task Outline: Provide a brief outline of the work to be accomplished during the Phase I effort.
Milestone Schedule
Deliverables
Progress reports
Final report with SF 298

Cost Volume: Cost information should be provided by completing the Cost Volume in DSIP 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. Provide sufficient information (a-i below) regarding funds use if an award is received. The DSIP Cost Volume and Itemized Cost Volume Information will not count against the specified page limit. The itemized listing may be submitted in Volume 5 under the "Other" dropdown option.

a. **Special Tooling/Test Equipment and Material**: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness to the work proposed. Special tooling and test equipment purchases must, in the CO's opinion, be advantageous to the Government and relate directly to the effort. It 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, prices and where appropriate, purpose.

c. **Other Direct Costs**: This category includes, but is not limited to, specialized services such as machining, milling, special testing or analysis, and costs incurred in temporarily using specialized equipment. Proposals including leased hardware must include an adequate lease vs. purchase justification.

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

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

f. **Subcontracts**: Involvement of university or other consultants in the project's planning and/or research stages may be appropriate. If so, describe in detail and include information in the Cost Volume. The proposed total of consultant fees, facility lease/usage fees, and other subcontract or purchase agreements may not exceed **one-third of the total contract price** or cost (do not include profit in the calculation), unless otherwise approved in writing by the CO. The SBIR funded work percentage calculation considers both direct and indirect costs after removal of the SBC's proposed profit. Support subcontract costs with copies of executed agreements. The documents must adequately describe the work to be performed. At a minimum, include a Statement of Work (SOW) with a corresponding detailed Cost Volume for each planned subcontract.

g. **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 the hourly rate.

NOTE: If no exceptions are taken to an offeror's proposal, the Government may award a contract without negotiations. Therefore, the offeror's initial proposal should contain the offeror's best terms from a cost or price and technical standpoint. If there are questions regarding the award document, contact the Phase I CO identified on the cover page. The Government reserves the right to reopen negotiations later if the CO determines it to be necessary.

h. DD Form 2345: For proposals submitted under export-controlled topics, either International Traffic in Arms or Export Administration Regulations (ITAR/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. DD Form 2345 approval will be required if proposal if selected for award.

NOTE: Restrictive notices notwithstanding, proposals may be handled for administrative purposes only, by support contractors TEC Solutions, Inc., APEX, Oasis Systems, Riverside Research, Peerless Technologies, HPC-COM, Mile Two, Wright Brothers Institute, and MacB (an Alion Company). 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. Contact the AF SBIR/STTR COs with concerns.

Company Commercialization Report (CCR) (Volume 4)

Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD SBIR Program BAA for full details on this requirement. Information contained in the CCR will not be considered by the Air Force during proposal evaluations.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)

The Air Force does not participate in the Discretionary Technical and Business Assistance (TABA) Program. Proposals in response to Air Force topics should not include TABA.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Firms shall register in the System for Award Management (SAM), https://www.sam.gov/, to be eligible for proposal acceptance. Follow instructions therein to obtain a Commercial and Government Entity (CAGE) code and Dunn and Bradstreet (DUNS) number. Firms shall also verify "Purpose of Registration" is set to "I want to be able to bid on federal contracts or other procurement opportunities. I also want to be able to apply for grants, loans, and other financial assistance programs", NOT "I only want to apply for federal assistance opportunities like grants, loans, and other financial assistance programs." Firms registered to compete for federal assistance opportunities only at the time of proposal submission will not be considered for award. Addresses must be consistent between the proposal and SAM at award. Previously registered firms are advised to access SAM to ensure all company data is current before proposal submission and, if selected, award.

Please note the FWA Training must be completed prior to proposal submission. When training is complete and certified, DSIP will indicate completion of the Volume 6 requirement. The proposal cannot be submitted until the training is complete. The AF recommends completing submission early, as site traffic is heavy prior to solicitation close, causing system lag. **Do not wait until the last minute.** The AF will not be responsible for proposals not completely submitted prior to the deadline due to system inaccessibility unless advised by DoD.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in the 22.1 SBIR DoD announcement in descending order of importance with technical merit being most important, followed by principal investigator's (and team's) qualification, followed by the potential for commercialization as detailed in the Commercialization Plan.

The AF will utilize the Phase II proposal evaluation criteria in the 22.1 SBIR 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).

Proposal Status and Feedback

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.

Feedback will not be provided for Phase I proposals determined Not Selectable. Feedback will be provided only for Phase II proposals determined Not Selectable.

IMPORTANT: Proposals submitted to the AF are received and evaluated by different organizations, handled topic by topic. Each organization operates within its own schedule for proposal evaluation and selection. Updates and notification timeframes will vary. If contacted regarding a proposal submission, it is not necessary to request information regarding additional submissions. Separate notifications are provided for each proposal.

It is anticipated all the proposals will be evaluated and selections finalized within approximately 90 calendar days of solicitation close. Please refrain from contacting the BAA CO for proposal status before that time.

Refer to the DoD SBIR Program BAA for procedures to protest the Announcement.
As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: Air Force SBIR/STTR Contracting Officers.

AIR FORCE SUBMISSION OF FINAL REPORTS

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

PHASE II PROPOSAL SUBMISSIONS

AF organizations may request Phase II proposals while technical performance is on-going. This decision will be based on the contractor's technical progress, as determined by an AF Technical Point of Contact review using the DoD 22.1 SBIR BAA Phase II review criteria. All Phase I awardees will be provided an opportunity to submit a Phase II proposal unless the Phase I purchase order has been terminated for default or due to non-performance by the Phase I company.

NOTE: Air Force primarily awards Phase I and II contracts as Firm Fixed Price. However, awardees are strongly urged to work toward a Defense Contract Audit Agency (DCAA) approved accounting system. If the company intends to continue work with the DoD, an approved accounting system will allow for competition in a broader array of acquisition opportunities. Please address questions to the Phase II CO, if selected for award.

All proposals must be submitted electronically via DSIP by the date indicated in the Phase II proposal instructions. Note: Only ONE Phase II proposal may be submitted for each Phase I award.

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 22.1 SBIR Phase I Topic Index

AF221-0022 Explainable AI (XAI) for RF Applications of Deep Learning

AF221-0023 Energy Deposition Systems for Scramjet Engine Ignition and Combustion Augmentation

AF221-0024 Innovative Concepts for Runtime Assurance Technologies

AF221-0025 Autonomous Sensing of Defense Tactical Targets by LEO Imaging Systems

AF221-0026 Signal Processing Techniques to Enhance Anti-Jam Performance for Low SWAP-C M-Code-based GPS User Equipment

AF221-0027 Autonomous Target Track Management by Proliferated Space Constellations

AF221-0028 Novel Analytics for Characterizing Influence in Visual and Audio Social Cyber Data

AF221-0029 Big Data Analytics for Managing and Parsing Computational and Experimental Data

AF221-0030 Event-Based Infrared Read-Out Integrated Circuit for Neuromorphic Processing

AF221-0031 Publicly Available Information (PAI) Collection Management

AF221-0032 Low-Cost Scalable Ultrawideband Receiver Personality for Attritable Platforms

AF221-0033 Evolvable Software Workbench for Avionics Cyber Security

AF221-0001 TITLE: Experimental Digital Twins for Multi-GNSS Integrity Monitoring

TECH FOCUS AREAS: Network Command, Control and Communications; Autonomy; Artificial Intelligence/Machine Learning; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Sensors; Space Platform; Information Systems

OBJECTIVE: Develop experimental digital twin concepts for "eCreate before You Aviate" offering new digital engineering perspectives to competitive market-driven acquisition of Multi-GNSS Integrity Monitoring systems, e.g., in how US Space Force should effectively integrate and operate multi-GNSS software-defined receivers equipped with reprogrammable multi-GNSS integrity monitoring for increased anti-jam performance, signal flexibility, SWaP-C reduction, and increased supplier base.

DESCRIPTION: US Space Force is interested in exploring the value to Multi-Global Navigation Satellite System (Multi-GNSS) of recent developments in digital twin applied to position, velocity, and timing (PNT) information with different levels of integrity, accuracy, continuity, and reliability in GNSS-challenged environments. Digital twining is now an important and emergent design and development trend in many applications such as health, meteorology, manufacturing and process technology, etc. It is best known as a virtual representation of physical assets enabled through data and simulators for real-time forecast, optimization, monitoring, retrospective analysis, and improved decision-making. Multi-GNSS and multi-GNSS integrity monitoring applications could include exploitation of redundancy of observables available from legacy and modernized civil signal operations including non-GPS data sources, detection and identification of possible anomalies corrupting navigation solutions, and receiver autonomous integrity monitoring. Such technical areas typically involve multi-constellation GNSS physically in real-time, inbuilt spoof detection at GNSS navigation receivers, scenarios and integrity risk assessment, statistical hypothesis testing, availability of simulated and live-fed data and advanced analytics in real time. The topic solicitation envisions that the breakdown of an experimental digital twin should be consisted of three pillars: i) Virtual Twin – creation of virtual representations of different environments and available infrastructures (e.g., with dedicated infrastructure, with ad-hoc infrastructure or with no infrastructure at all), platform dynamics of multi-constellation GNSS, Inertial Measurement Units (IMUs), multi-GNSS receivers accessing a large number of ranging signals from multi-GNSS constellations via S and L bands, real-time IMU measurements, and the possible levels of hybridization within multi-GNSS integrity monitoring systems together with distributed telemetry, tracking and commanding (TT&C) data from control segments and user segments; ii) Predictive Twin – physics based, data driven or hybrid models operating on the virtual twin to predict the requirements for continuous, accurate and robust PNT services, including characterization of spoofing and navigation errors caused by multi-path propagation as well as signal accuracy and availability; and iii) Twin Projection – Integration of insights generated by the predictive twin into the proof of concept of multi-GNSS software-defined receivers equipped with reprogrammable multi-GNSS integrity monitoring for pseudo ranging operations. Proposed solutions are expected to demonstrate the feasibility of applying high-fidelity numerical simulators, physics-informed machine learning and artificial intelligence, data assimilation, hardware and software in the loop, etc. to multi-GNSS systems, received signals for any coverage services, and multi-GNSS integrity monitoring systems. Quantification of experimental characteristics and capabilities such as continuous updates with total integrity risk of positioning errors in near real-time, physical realism at high spatio-temporal resolutions, informed decision-making, and future predictions to be achieved is highly desirable.

PHASE I: Identify relevant characteristics, e.g., infrastructures, platform dynamics, multiple hypothesis solution separation techniques associating with potential multi-GNSS and multi-GNSS integrity monitoring applications and mapping them to corresponding enabling technologies with which digital twins have been previously demonstrated and evaluated for real-time communication of data and latency, physical realism and future projections, continuous model updates and modeling the unknown. Investigate new techniques, methods, and algorithms of representing the effects of GPS spoofing, multi-path propagation, and other factors affecting positioning errors to enable the feasibility of multi-GNSS, Inertial Navigation Systems, and multi-GNSS integrity monitoring applications of experimental digital twin technologies. Specify underlying datasets (e.g., live-fed INS, non-GPS core data, simulated/emulated GNSS signals, etc.) available for research and validated model building, and computational infrastructures.

PHASE II: Develop of an engineering development unit (EDU) to demonstrate the value of such an experimental digital twin in combination of live feeds of C/A and/or M-Code signals, to a continuous, accurate and robust service provision only offered by the multi-GNSS integrity monitoring, of which single GNSS integrity monitoring alone could not meet. Test out hypothetical scenarios for “what if?” analysis, performance gains and risk assessments of countering threats to integrity and exclusivity. Demonstrate physics/knowledge/science-informed machine learning as needed to enable the hybridization of a suite of different GNSS integrity monitoring solutions in addressing operational challenges of data management, data privacy and security, and data quality. Assess quantitative benefits, e.g., near real-time prediction of PNT resiliency in presence of ambiguity resolution of ephemeris, clock errors, interferences, etc. of using the digital twin EDU.

PHASE III DUAL USE APPLICATIONS: With the findings from Phase I and II, the construction of experimental digital twins will help the design of robust and resilient multi-GNSS, multi-GNSS receivers, multi-GNSS integrity monitoring systems and approaches not only during the conceptualization, prototyping, testing and design optimization phase but also during the operation phase with the ultimate aim to use them throughout the whole product life cycle. Potential Phase III military applications include enterprise tech solutions for robust, resilient PNT capabilities with anti-jam, anti-spoof, accuracy, integrity, and signal flexibility. Tech transition plan: Government organizations such as AFRL and SMC sponsor a government reference design of an experimental digital twin of multi-GNSS integrity monitoring systems in collaboration with small business and industry partners. Successful technology demonstrations will inform the technical requirements of future multi-GNSS integrity monitoring acquisitions by Primes and subcontractors. Improved multi-GNSS integrity monitoring and reprogrammability are generally in demand and thus are widely used in proliferated PNT and open architectures across all orbits.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

REFERENCES:

1. B. Hicks. Industry 4.0 and Digital Twins: Key Lessons From NASA. Accessed: Aug. 5, 2019. [Online]. Available: https://www.thefuturefactory.com/blog/24
2. Oracle. Digital Twins for IoT Applications: A Comprehensive Approach to Implementing IoT Digital Twins. Accessed: Sep. 10, 2019. [Online]. Available: http://www.oracle.com/us/solutions/internetofthings/digitaltwins-for-iot-apps-wp-3491953.pdf
3. W. Roper. There is No Spoon: The New Digital Acquisition Reality, Official Purpose Only, 2020

KEYWORDS: Multi-GNSS; multi-GNSS receivers; multi-GNSS integrity monitoring; simulated/emulated GNSS signals; live fed INS measurements; non-GPS signals; digital twin; virtual twin; predictive twin; twin projection; PNT reprogrammability

TPOC: Khanh Pham,
Phone: 505-846-4823
Email: khanh.pham.1@us.af.mil

AF221-0002 TITLE: Low C-SWaP EO/IR Sensor Technology for Attritable Platforms

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this topic is to develop low cost, size, weight, and power (C-SWaP) electro-optic/infrared (EO/IR) sensing technologies and capabilities that can be incorporated onto attritable platforms. The resultant sensing technology/capability will support air-to-ground mission areas in contested environments. Example mission areas include intelligence, surveillance and reconnaissance (ISR); target detection; and target identification.

DESCRIPTION: Future engagements may necessitate operations in contested environments, thereby putting high value platforms and associated sensors at risk. As such, future missions may utilize lower cost, attritable platforms to minimize those risks and provide support operations in contested environments. Objective EO/IR sensing technologies planned for attritable platforms have significant C-SWaP constraints over traditional platforms. Given the recent proliferation of small unmanned aerial vehicle technologies in the commercial sector, attritable platforms are experiencing significant development and maturation in their own capabilities. With the advent of new low C-SWaP EO/IR sensing technologies and capabilities that can couple with such platforms, the types of commercial applications able to leverage the combined technology becomes very broad (e.g., including but not limited to precision agriculture, land surveying, and environmental monitoring).

To advance toward the objective technologies and capabilities for the air-to-ground mission, many EO/IR sensing topologies are under consideration from imaging to non-imaging schemes using passive and/or active EO/IR sensing modalities. Examples include, but are not limited to: broadband EO/IR, multi-spectral, hyperspectral, polarimetric, direct-detect lidar, coherent lidar, vibrometry, etc. Research and development can include full system-level designs or advancement of component technology. Along with such development, physics-based and performance-based modeling and simulation of components and system-level designs are necessary to aid in evaluation of expected performance and in the development of a Concept of Operations (CONOPS). Examples of component and system-level designs include, but are not limited to: detectors, photonics, telescopes, transmitters, receivers, spectrometers, etc.

Currently, no attritable platforms have been identified to represent an objective platform. However, a minimum operating altitude requirement of 30 kft (T) is specified in order to provide rationale to any offeror-derived requirements/justifications for their proposed EO/IR sensing technology/capability. No government-furnished equipment, data, and/or facilities will be provided.

PHASE I: Develop necessary plans and concept designs for the proposed EO/IR technology or capability in order to demonstrate its viability. Include appropriate initial laboratory demonstrations as required.

PHASE II: Develop and execute detailed plans and designs for the proposed EO/IR technology or capability. Develop the model and simulation capability of the proposed EO/IR technology or capability in order to support CONOPS development. Develop breadboard prototype demonstrating the proposed EO/IR component or system.

PHASE III DUAL USE APPLICATIONS: Develop, refine, and execute detailed plans and designs for the proposed EO/IR technology or capability to be inserted onto an attritable platform. Develop and refine the model and simulation capability of the proposed EO/IR technology or capability in order to support CONOPS development for a designated military/commercial application. Develop a flight representative prototype demonstrating the proposed EO/IR component or system on an attritable platform in support of a designated military/commercial application.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

REFERENCES:

1. Chan, S., Halimi, A., Zhu, F. et al. Long-range depth imaging using a single-photon detector array and non-local data fusion. Sci Rep 9, 8075 (2019). https://doi.org/10.1038/s41598-019-44316-x
2. Kim, J., Oh, C., Serati, S. A., and Escuti, M. J., “Wide-angle, nonmechanical beam steering with high throughput utilizing polarization gratings,” Applied Optics, 50 2636 (2011);
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KEYWORDS: attritable; low-cost; sensor; sensing; optical; electro-optical/infrared; EO/IR; passive EO/IR; active EO/IR; broadband EO/IR; multi-spectral; hyperspectral; polarimetric; LIDAR; direct-detect LIDAR; coherent LIDAR; vibrometry; optical detectors; photonics; telescopes; optical transmitters; optical receivers; spectrometers; low-cost imaging; low-cost EO/IR sensing

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AF221-0003 TITLE: Effect of Control Surface Damage and External Defects on System Flight Dynamics

TECH FOCUS AREAS: Directed Energy; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a flight dynamics model capable of assessing the impact of externally generated defects in the outer mold line or control surfaces on the overall flight stability for high-speed aircraft and missiles.

DESCRIPTION: Defects on the outer mold or control surfaces of a high-speed system may lead to flight instability. Understanding the extent to which these defects alter system performance, dynamics, and controllability is crucial to system design. For the purposes of this topic, both the aerodynamic performance and flight dynamics of aircraft and highly maneuverable missile systems are of interest. Aerodynamic performance is typically described using static quantities such as the lift and drag coefficient. Flight dynamics are generally described in terms of aerodynamic stability derivatives, which includes terms that are both static and dynamic in nature. Accurate computation of the aerodynamic coefficients and full set of stability derivatives is essential to meeting the topic objectives, to include derivatives related to control surface actuation. Computational methods to assess aero-mechanics and flight dynamics include panel-based methods and volume-based computational fluid dynamics (CFD). Panel methods allow fairly rapid parametric variation of airframe properties and are computationally efficient and accurate for typical aircraft configurations but are not designed to represent fine-scale details such as surface defects and the mathematical formulations are likely incapable of doing so. CFD models the aircraft geometry in much finer detail but incurs a significantly higher modeling and computational cost due to the higher fidelity involved. Additionally, most CFD formulations are led for either steady-state or time-domain solutions which can provide static aerodynamic characteristics but do not directly yield the dynamic stability derivatives required for accurate flight dynamic assessment. To address these shortcomings, responses to this topic should propose a method computing the aerodynamic coefficients along with the static and dynamic stability derivatives of an aircraft subjected to parametric variations (size, shape, location, etc.) of one or more external defects. The method should enable the parametric alterations to be modeled in a reasonably automated manner requiring minimal analyst input. The method should correctly account for propulsive effects on the flowfield and aircraft flight dynamics, along with the potential to model damage to control surfaces and the associated impacts on vehicle control. Near-term applications are focused on the low-speed flight regime, but the method should be applicable at high subsonic and supersonic speeds as well. Although accurate aeromechanical modeling of the external defects is the primary goal, priority should also be given to developing a computationally efficient method that can feasibly simulate large numbers of parametric variations without requiring excessive schedule or computational resources. Candidate numerical methods which may fulfill the criteria include, but are not limited to, the use of alternatives to traditional CFD such as Lagrangian vortex methods [1], application of system identification procedures within a time-domain CFD solver [2] or use of frequency-domain CFD to directly compute stability derivatives [3].

PHASE I: Develop a simple prototype model or demonstrate the numerical strategy for computation of aerodynamic coefficients, stability derivatives, and a corresponding flight dynamics model. Using a notional test case, derive these parameters using a high-fidelity baseline (e.g., time-domain CFD results) to be used as a verification dataset.

PHASE II: Define a user-focused workflow to enable efficient definition of parametric defect sets, calculation of aerodynamic derivatives, and demonstration of defect impact on flight dynamics. Mature the prototype into a functional tool, to include a graphical interface and user documentation. Validate flight dynamic calculations using either wind tunnel or free-flight testing of a scaled model vehicle.

PHASE III DUAL USE APPLICATIONS: Unify the method with external solvers capable of computing realistic defect geometry. Investigate enhancements to computational efficiency to broaden the range of configurations which can be considered on a given schedule. Extend the method to account for aeroelastic effects and weakening of the underlying substructure to enable a larger range of system effects to be considered.

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[3] Jacobson, K., Stanford, B., Wood, S., & Anderson, W. K. (2020). Flutter Analysis with Stabilized Finite Elements based on the Linearized Frequency-domain Approach. In AIAA Scitech 2020 Forum (p. 0403).

KEYWORDS: Computational fluid dynamics; high speed flow; panel methods; flight dynamics; flight stability; surface defects; aerodynamics, aircraft; missiles

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AF221-0004 TITLE: Programmability of Niche Military Open Architectures

TECH FOCUS AREAS: Network Command, Control and Communications; Autonomy; Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Sensors; Information Systems

OBJECTIVE: Develop programmability aid technologies to enable broad adoption of military sensor software focused open architectures.

DESCRIPTION: Open architectures (OAs) provide mechanisms for faster technology refresh, technology insertion, and enable a more competitive market. Adoption drives many of the benefits of OAs by allowing reuse and transfer of technology between systems. To be successful an OA must be published, public, and popular. However, many OAs struggle with adoption once published and public. Due to the timelines involved in OA development, they can emerge with outdated or insufficient programmability aids. The Air Force seeks solutions to enable broad adoption of emerging software focused Open Architectures including STITCHES, COARPs, and OMS. Phase I work will focus on COARPs, enabling the rapid integration of radar sensors, processors, and modes. Ideas may include but are not limited to: IDE improvements for automatic code generation or validation, integrated training, DevOps integrations, integration of data ingesters, playback tools, or any other programmability aids that can be shown to ease transition/adoption or modernize software development workflows. Acronyms: SOSITE – STITCHES System of Systems Integration Technology and Experimentation (SoSITE) - SoS Technology Integration Tool Chain for Heterogeneous Electronic Systems (STITCHES) COARPs: Common Open Architecture for Radar Programs OMS: (Open Mission Systems)

PHASE I: Determine appropriate programmability solutions. Consolidate lessons learned from multiple COARPs mode development projects into a technology implementation roadmap and adoption focused strategy to implement through technology development and insertion in Phase II.

PHASE II: Phase II will consist of expanding on and implementing the solution developed in Phase I. The programmability and adoption roadmap developed in Phase I will be prototyped and additional lessons learned developed. Phase II will require working directly with mode and software developers on detailed requirements definition for the programmability aids.

PHASE III DUAL USE APPLICATIONS: Phase III will focus on maturing the prototype technologies and processes developed in Phase II into commercial technologies. While potential commercial application and potential commercial customers are important in all three phases (especially to aid in requirements definition and feedback), they are especially important to success in Phase III. COARPs is a dual use technology, and it is expected that radar developers will be the primary customer of the products of this SBIR, with the government benefiting through increased adoption of the standard by industry. Dual Use: A primary goal of open architectures and COARPs in particular is to enable small businesses and non-traditional tech providers to be competitive in traditionally OEM/Prime and military industry areas. COARPs enables radar software development by 3rd parties, enabling a growing commercial sector for these technologies.

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1. COARPs Program Virtual Distributed Laboratory (VDL): Contact Austin Klaus for access DAU Definition of Open Architectures:
https://www.dau.edu/glossary/Pages/GlossaryContent.aspx?itemid=28062

KEYWORDS: COARPs; Open Architectures; programmability; automatic code generation; code validation;

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AF221-0005 TITLE: Image-based COTS Bidirectional Reflectance Distribution Function (BRDF) Measurement

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Space Platform; Materials

OBJECTIVE: Develop an image-based system operated by a minimally trained operator for rapid BRDF generation.

DESCRIPTION: Generating realistic and radiometrically accurate images of modeled scenes, both for computer graphics and remote sensing applications, requires a complete description of the reflection from all material surfaces in the scene at all incidents and reflected angles and all wavelengths of interest. This description of the reflective behavior is commonly referred to as the BRDF. Many mathematical models describing the BRDF exist, some better suited to certain classes of materials than others. However, they all contain material-specific parameters that are not readily available and in the best case are derived from measured BRDF data. Instruments to make BRDF measurements are generally highly specialized, purpose-built, rare, and expensive. The measurements are also time-intensive and thus usually sparsely sampled. These drawbacks have been successfully addressed by previous efforts to generate BRDFs using an image-based technique.1 These efforts utilized multiple cameras to illuminate a curved sample at different angles and capture many reflected angles simultaneously in each image. Computer vision and image post processing eliminates the need for precise positioning and generates millions of separate reflection measurements that cover the whole reflection hemisphere. However, the imaged-based system previously developed was a proof-of-concept instrument requiring expert operation and image processing. For a space domain awareness utility, this methodology has not been integrated into a commercially available system that can be operated by a minimally trained operator for rapid BRDF generation. Also, in the years since, enabling technologies have developed to further decrease the barrier to entry to performing these measurements, including cell phone cameras, 3D printing, and app-based software. Decreasing equipment cost and increasing user-friendliness would enable image and computer vision based BRDF measurement of individual materials over representative samples, on-site measurements, and more commonplace use of measurements over BRDF estimates. BRDF are generally used for: • Material identification of spacecraft surfaces for space domain awareness • Characterization and identification for RSO (Resident Space Objects), aircraft, and missiles • Understanding lighting conditions in an image due to foreign light sources (albedo, planetshine, retroreflection, ringshine, etc) • Modeling visible "glints" in space and aerospace applications • Rendering for computer applications and video processing

PHASE I: An initial solution to this topic would include the basic hardware required to re-create the image based BRDF generation demonstrated by Marschner, as detailed in reference 1. This would include the sample and camera mounts and COTS cameras to capture the necessary BRDF images. However, the major effort is in developing the software to enable BRDF generation. This includes computer vision algorithms to automatically generate the relative angles in the scene from the images themselves, combination/averaging of image pixels representing the range of BRDF angles, and fitting of the data to several popular BRDF models. Emphasis in the development is to be placed both on precision of the measurement and on reducing the investment necessary in the system. This could range from a bare-bones approach utilizing 3D printed parts and cell phone cameras, to specialized mounts and photographer-grade digital cameras.

PHASE II: Phase II efforts would seek to decrease the total cost of the system and the skill level and input required by the user. This may include transitioning from professional-grade cameras to consumer-grade or cell phone cameras, deriving more of the necessary inputs from the images themselves, rather than user inputs, or developing analysis software that self-guides the user through the BRDF generation process.

PHASE III DUAL USE APPLICATIONS: Phase III efforts would create a mass market product utilizing widely available hardware (ideally cell phone cameras) and packages the analysis software into a cell-phone application. This would allow BRDFs of individual materials or objects (rather than representative articles) to be captured on site and used to populate models for remote sensing or imported into individualized computer-generated scenes.

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1. Stephen R. Marschner, Stephen H. Westin, Eric P. F. Lafortune, and Kenneth E. Torrance, "Image-based bidirectional reflectance distribution function measurement," Appl. Opt. 39, 2592-2600 (2000)

KEYWORDS: Modeling and Simulation; Remote Sensing; Computer Vision; Space Domain Awareness; Image Rendering/processing

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AF221-0006 TITLE: Mid-Infrared High Efficiency Broadband Diffraction Gratings for Ultra-Short Pulse Compression

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Space Platform; Air Platform

OBJECTIVE: This topic addresses the broadband nature of ultrafast optics and increase the efficiency of the diffractive elements in the Mid-InfraRed (MIR). Technological research areas which may enable reaching high efficiencies across broad bandwidths in the MIR include Ultrafast Laser Inscription (ULI) direct-writing of substrates [1], nano-structured substrate treatments to produce broadband anti-reflection properties [2], utilization of novel chalcogenide MIR substrates for transmission gratings [3], and engineered surface structures designed for multiple coupled blazing resonances [4]. The proposed technology should provide 94%+ diffraction efficiency in reflection or transmission across a minimum of 5% bandwidth wavelength range suitable for lasers operating between 3 µm and 5 µm, in addition to having high-power handling capabilities (>10 mJ), either via coating damage threshold or large substrates.

DESCRIPTION: Ultra-Short Pulse Laser (USPL) technology in the MIR is currently investigated for Directed Energy (DE) applications at AFRL. Recent studies have indicated that losses in power at target due to propagation through the atmosphere can be significantly reduced using USPL (femtosecond) systems operating in the MIR between 3-5µm. This is primarily due to two factors: 1) atmospheric transmission windows are more prevalent in the MIR than visible-NIR wavelengths, where molecular absorption lines can produce severe limitations on how much energy can be delivered at target as a function of distance, and 2) the critical power for producing a single-filament scales quadratically with wavelength. Much of the physics for USPL propagation involves a phenomenon called filamentation [5-6] that can potentially enable delivery of high intensities to targets at distances that are much greater than expected by diffraction-limited beams. The power in a filament is limited to a so-called Critical Power (Pc) which increases proportional to the square of the wavelength (Pc ~ λ2). For powers much higher than Pc for a given laser, modulation instabilities occur that cause the beam to break up into multiple filaments. Mid-Infrared USPLs will therefore propagate at much higher powers and for longer distances than NIR USPL systems before experiencing energy losses due to the formation of multiple filaments [7]. Furthermore, recent studies of Si and Ge [8-10] indicate that less fluence is required to damage semiconducting materials with a MIR USPL than with a NIR USPL because the damage threshold is reduced as the wavelength is increased. The ability for MIR USPLs to experience low-loss propagation through the atmosphere along with an increased efficacy in producing damage on-target offers a promising new avenue for producing low-SWaP Directed Energy platforms for military utility. However, in order for MIR USPL systems to be fielded in a military environment, higher efficiency elements are needed to improve the overall throughput, in addition to materials which can support the bandwidth necessary to produce ultra-short pulse operation. One of the most significant factors contributing to excess loss in MIR USPLs is the lack of availability of efficient MIR diffraction gratings to allow for pulse compression below 100 femtoseconds. While current state-of-the-art technology (COTS products) are capable of producing high peak diffraction efficiencies (>95%), the efficiency quickly degrades outside of the design wavelength. The result is that the average intensity across sufficient bandwidth to produce.

PHASE I: Develop concepts illustrating a proof-of-concept design. This should include details 1) describing how the design(s) demonstrate manufacturability, 2) addressing how technical challenges would be addressed, and 3) discussing how concepts may be reasonably scaled to accommodate a range of specifications for laser systems between 3-5 µm.

PHASE II: Design/construct/deliver set (2x) of prototype diffraction gratings, either reflection or transmissive. Each grating should be tuned for a central wavelength of 3.8 µm, and must maintain a diffraction efficiency of 94% or better across sufficient bandwidth to support 10mJ) pulses, either by supporting a high-damage threshold, or by being large enough to support beam sizes sufficient to decrease the energy density to acceptable levels given the material. Each grating must have an identical groove density, which should be large enough to be suitable for pulse compression (>350 lines/mm).

PHASE III DUAL USE APPLICATIONS: Military application: Define product line for standard packages suitable for ruggedized applications on deployable platforms. Commercial application: Define product line for standard packages suitable for commercially available MIR laser sources to be used in research laboratories within Gov't agencies, national laboratories, academic laboratories, and other research institutions.

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KEYWORDS: Mid-Infrared; MIR; femtosecond; compressor; femtosecond; diffraction grating; OPA; OPCPA; OPA; USPL; Multi-Layer Coatings; Nano-Textured; Efficient Diffraction;

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AF221-0007 TITLE: RF System Response and Analysis

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Electronics; Air Platform

OBJECTIVE: Analysis performed under this topic will be used to develop the capability to utilize these detailed predictive models for systems of interest to the Air Force and other DoD entities. The Air Force seeks tools capable of evaluating system performance of an actively tracking RF seeker system subject to HEL irradiation.

DESCRIPTION: This topic explores the current state of the art related to RF tracking systems. Offerors will select a surrogate system to conduct testing and measure response of damage testing. Utilizing high fidelity modeling and simulation tools selected, support system analysis related to degradation and mission level impact and conduct active system testing to evaluate utility of predictive capability conducted prior to test activity. End goal is to have a robust predictive capability.

PHASE I: Selecting a system of interest, develop a model using currently available RF models to develop a system performance simulation. Simulation will run expected HEL engagements, developing test matrices for Phase II efforts.

PHASE II: Conduct HEL engagement tests to evaluate simulation results providing necessary data critical for developing robust simulation capabilities.

PHASE III DUAL USE APPLICATIONS: Develop a robust predictive capability to support HEL engagement of RF systems used for both red and blue analysis and response supporting mission utility studies and AoA analysis efforts.

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3. https://patents.google.com/patent/US8765230B1/en;
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6. https://www.sciencedirect.com/science/article/pii/S2452321619300125

KEYWORDS: RF missiles; HEL response; RF system response; mission analysis

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AF221-0008 TITLE: Satellite and Debris Discrimination and Identification

TECH FOCUS AREAS: Directed Energy; Network Command, Control and Communications; Autonomy

TECHNOLOGY AREAS: Sensors; Information Systems; Battlespace

OBJECTIVE: This topic seeks new methodologies to characterize and discriminate between classes of space objects using available sensing and imaging technologies and be compatible with future imaging ground and space-based assets. The proposed approach should be extensible to autonomous and rapid operation.

DESCRIPTION: The growing number of man-made resident space objects (RSOs) orbiting the Earth poses a potential threat to US space assets and, therefore, to US national security. These RSOs include working satellites, used rocket stages, space debris, in-operable satellites, and other man-made space objects. All these objects represent various levels of threat and require different handling based on RSO functioning and mission. We seek innovative research employing AI/Machine Learning Techniques to identify, categorize, and characterize space objects in real data.

PHASE I: Develop understanding of real-world data and relevant characteristics of space objects to study the problem. Consider both ground-based and space-based observation [Murray-Krezan, et al, 2019] systems. This topic seeks new methodologies to characterize and discriminate between classes of objects using available sensing and imaging technologies and compatible with developing future imaging ground and space-based assets. The proposed approach should be extensible to autonomous and rapid operation. Consider size and illumination conditions for RSOs at various orbits, only dim and low-resolution images and light curves of these objects can be obtained. Use of advanced modern image processing techniques in combination with multispectral and hyper-temporal modalities can be explored. Considering the wide variety of RSO characteristics, machine learning techniques grounded in physical attributes may be employed.

PHASE II: Early phase research will develop and demonstrate the method to distinguish different classes of RSO using synthetic data (note: if AF satellite imagery data, real or simulated, is available for public release that would be ideal). An algorithm to estimate speed (in CPU hours) and accuracy of the method achievable under a variety of observation conditions (large ground-based telescope, space-to-space engagement, LEO, GEO etc.) will be developed. Later phase research will build and demonstrate a prototype end-to-end software/firmware system.

PHASE III DUAL USE APPLICATIONS: AI machine learning techniques developed can be adapted to technical problems across DoD and commercially.

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KEYWORDS: Space domain awareness; machine learning; AI, space debris; multispectral; space control

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AF221-0009 TITLE: Enabling Thermal Solutions for Future Laser Weapon Systems

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Electronics; Materials; Air Platform; Battlespace

OBJECTIVE: Perhaps the most critical obstacle limiting the scalability of Laser Weapon Systems is rugged, low volume and weight thermal dissipation architectures. Lightweight, compact system thermal management begins in the laser source itself.

DESCRIPTION: High Energy Laser Weapon Systems must perform in a highly transient environment with periodic short duration engagements in a rugged military environment in ground or air vehicles. Given current and projected efficiencies, a 300kWo class laser would require dissipating in excess of 600kWt of heat. For a 30s engagement magazine this equals 18MJt of energy to store or reject. Current laser source thermal architectures are not able to take advantage of the lightweight, compact thermal solutions that are currently being developed, largely due to issues such as low-quality heat and high flow rates within the laser source itself. The following ideas are suggestive, not prescriptive. Any solution within the laser source for enabling lightweight, compact and rugged thermal architectures for High Energy Laser Weapon Systems is of interest. Areas of interest include but are not limited to: • Two-phase coolant systems • 'Common loop' cooling solutions • High-temperature diodes • Novel heatsink materials and geometries • Vapor chamber cooling • Low-flow, low pressure solutions • Lightweight, high efficiency/performance pumps • Passive thermal transient management. Combinations of the above approaches are also of interest. All solutions must take into account system level efficiencies and requirements of High Energy Laser Weapon Systems.

PHASE I: Offerors will propose a specific set of thermal management improvements and conduct design and feasibility study to validate assertions of high energy laser weapon system level SWaP improvement.

PHASE II: A successful phase II proposal will demonstrate technical feasibility at the system level by: -Construction of a TRL 4 prototype of the technology in question -Creation of a final report detailing the design and creation of said prototype -An outline of the "next-steps" needed to advance the prototype technology, as well as various paths said advances could take -A concept of how the prototype technology would fit into an HEL system architecture.

PHASE III DUAL USE APPLICATIONS: Phase III will build a drop-in upgrade to an existing ground or airborne high energy laser weapon system that will enhance existing capability of that system.

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3. Sean Ross, Travis Michalak. (2016) Laser-thermal interface parameters. Internal Briefing (available on request from Dr. Ross or myself)

KEYWORDS: Two-phase coolant systems; Common loop' cooling solutions; High-temperature diodes; Novel heatsink materials and geometries; Vapor chamber cooling; Low-flow, low pressure solutions; Lightweight, high efficiency/performance pumps; Passive thermal transient management

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AF221-0010 TITLE: Innovative Solutions for Laser Weapon Components, Devices, and Subsystems

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The objective of this topic is to advance the state-of-the-art in beam quality control in high energy lasers for directed energy applications through the development of a functional intra- or extra-cavity hardware/software implementation which would ultimately result in an innovative, robust, and scalable solution to actively monitor and control optical beam quality at multiple tens of kilowatts-optical continuous wave and multiple kilowatts-optical pulsed.

DESCRIPTION: The Air Force has identified High Energy Lasers as potential modern weapons as they offer the advantages of speed-of-light-delivery, multiple target engagements with rapid retargeting, deep magazines, low incremental cost per shot, exceptional accuracy and low logistical support requirements. As High Energy Lasers increase in power, their intra-cavity recirculating optical energy also increases, resulting in thermal loading in the laser cavity and, subsequently, optical path differences which negatively affect laser beam quality and effective range. In the effort to optimize power on target at range and prevent laser optics damage, there is much interest in pursuing innovative, robust, and scalable solutions to actively monitor and control optical beam quality at multiple tens of kilowatts-optical continuous wave and multiple kilowatts-optical pulsed with a wavelength of around 1 .m. Typical beam quality control solutions in open literature include wavefront sensors and deformable mirrors; therefore, a solution for High Energy Lasers may require advancement of the associated system components. Current areas of interest include but are not limited to the following: 1) innovative techniques to assess the health and status of High Energy Laser optics in-situ in near real-time, 2) innovative high-speed wavefront.

PHASE I: Establish feasibility of the proposed solution. Perform sufficient modeling and/or experimentation to determine high-risk components are attainable. Perform tradeoffs to establish a preliminary design leading for Phase II. Define a Phase II program plan. Identify and document endorsement from potential transition partners. Provide a thorough understanding of the solution to government in time to make a Phase II decision.

PHASE II: Finalize design of a demonstration prototype. Procure, develop, and integrate the solution prototype. Plan and coordinate one or more demonstrations to provide proof of concept determination. Perform experiments and analyze results to establish the adequacy of the solution approach and minimize transition risk. Contact potential customers and establish a transition plan with partners supporting Phase III activities. Provide regular communication to the government sponsor to ensure understanding and risk mitigation.

PHASE III DUAL USE APPLICATIONS: Integrate with prospective follow-on transition partners. The contractor will transition the solution to provide improved operational capability to a broad range of potential Government and civilian users and alternate mission applications.

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KEYWORDS: high energy/power laser; in-situ; real-time; beam quality (BQ); wavefront sensor (WFS); adaptive optics (AO); deformable mirror (DM)

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AF221-0011 TITLE: Multi-physics Modeling of the Ablation Process for Thermal Protection Systems

TECH FOCUS AREAS: Directed Energy; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Materials

OBJECTIVE: These efforts will develop a high-fidelity predictive capability to assess the ablation response of thermal protection system materials based upon first principles multi-physics models.

DESCRIPTION: The Air Force is researching materials with high ablation energies for use as thermal protection systems in extreme environments. Modeling the thermal degradation of these materials necessitates the use of an ablation response model (ARM). Traditional ARMs were designed with reentry applications in mind [1] and are not specifically tailored to address strong localized flux variations and the corresponding non-uniform ablation. ARMs typically rely on mass blowing (B-prime) tables to model the chemical reactions at the solid-fluid interface and assume equilibrium chemistry based on partial pressures and temperatures at the surface. B-prime tables can introduce a significant amount of uncertainty into the analysis as often times the required data can be difficult to obtain. Coupling an ARM with computational fluid dynamics (CFD) [2] can eliminate the need for B-prime tables but comes at considerable computational expense. Furthermore, the complex composite materials and surface coatings that are often used in thermal protection systems (TPS) present additional challenges for traditional ARMs. These materials and coatings can result in complex surface reaction mechanisms, which can increase the computational expense of simulation. The Air Force seeks advanced multiphysics tools for modeling ablation of TPS materials in highly non-linear heat flux environments and aero-assisted ablation due to surface defects for high-speed systems. In addition, enhanced tools are needed which can accurately model ablation of non-homogenous composite materials. The tools should require minimal supplemental data (e.g., B-prime tables) and be computationally efficient.

PHASE I: The Phase I proposal should focus on demonstrating the feasibility of one or more novel modeling ablation concepts under localized heating or aero-assisted ablation due to surface defects. The demonstrated concept should show an improvement over the state-of-the-art.

PHASE II: Phase II will validate the proposed tool using a composite material and non-uniform heat flux profile relevant to Air Force programs. Focus will be on extending the tool to higher fidelity analysis with the goal of modeling ablation due to hypersonic aeroheating through the full flight trajectory.

PHASE III DUAL USE APPLICATIONS: In Phase III, the firm will work with industry to make the novel concept widely available for material ablation simulation in a broad range of environmental conditions and materials. Relevant non-military applications may include the simulation of aircraft brake pad performance, rocket nozzle ablation and other high temperature material ablation problems.

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[2] Marschall, J., and M. MacLean. “Finite-Rate Surface Chemistry Model, I.” AIAA-2011-3783. 2011.

KEYWORDS: Ablation; surface chemistry; computational fluid dynamics; multi-physics model; thermal protection systems; composites, hypersonics

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AF221-0012 TITLE: Voice Control and Authentication on Mobile Tactical Systems

TECH FOCUS AREAS: Cybersecurity; Network Command, Control and Communications; Artificial Intelligence/Machine Learning; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Bio Medical; Sensors; Electronics; Information Systems; Battlespace

OBJECTIVE: This topic seeks hands-off voice/acoustic recognition for increased usability and interoperability with TAK. Additionally, synchronous and automatic user authentication for enhanced information security, using two factors of authentication (something you are and something you have) is also sought, as well as detection and identification of various sounds.

DESCRIPTION: In tactical environments, existing authentication mechanisms in TAK and mobile devices have proven to be insufficient or cumbersome for operators. Gloves and other gear can make it difficult to interact with the phone's screen for passcode or other forms of authentication requiring contact with the screen. Likewise, for the same reasons, it proves difficult to interact with and control ATAK (Android Team Awareness Kit) efficiently to disperse and assimilate information relevant to the mission. These deficiencies point to a need for hands-off TAK authentication, through voice biometrics and proximity-based access control, as well as voice command and control of TAK devices. The ability to extract information from voice-based radio communications and/or detect and identify non-vocal sounds in the environment (i.e., gunshots and vehicles) could also prove to be useful as part of this effort. Proximity-based access control includes the ability to grant or deny access based on proximity to friendly forces and teammates, enemy forces, military bases, etc. This research aims to explore voice biometrics, voice commands, and proximity-based access control as it relates to the TAK ecosystem.

PHASE I: For all sub-efforts: based on the research performed within this phase, develop a roadmap for development in Phase II and determine the scientific, technical, and commercial feasibility of the proposed solution. For proximity-based access control: demonstrate in a simulated environment the ability to perform proximity-based authentication based on distance from peers and/or established locations. For voice authentication: identify strategies to mitigate vulnerabilities and exploits inherent in many voice authentication implementations, such as the replay and synthesis attacks, and explore the feasibility of detecting duress in an operator's voice to prevent coerced, unauthorized access. For voice command and control (VC2): demonstrate ability to perform very basic control of ATAK via voice and determine areas of future work for Phase II. For both VC2 and voice authentication: research techniques to minimize the effects of background noise in a tactical environment (e.g., shouting, gunshots, engines) while maintaining a low false negative rate for authentication and increased reliability for command and control. Incorporate all of these techniques into a proposed solution that provides offline voice authentication, proximity-based access control, and VC2 for mobile devices.

PHASE II: Implement the roadmap established during Phase I. Collect data and/or utilize public datasets as needed. Obtain necessary hardware (e.g., mobile phones), then implement and test the proposed solution. Demonstrate the solution's capability in tactical environments and revise as necessary to improve reliability and security, gathering and incorporating end-user feedback when possible. Develop a plan for Phase III.

PHASE III DUAL USE APPLICATIONS: A commercial solution for proximity-based access control, voice authentication in tactical and loud environments, and VC2 would be marketable to military and first-responder users of ATAK, as well as other users who simply desire enhanced voice recognition in tumultuous environments.

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KEYWORDS: TAK; Biometrics; Authentication; Voice

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AF221-0013 TITLE: Personnel Recovery Search and Evasion Guidance Planning Artificial Intelligence / Machine Learning Model Development

TECH FOCUS AREAS: Autonomy; Artificial Intelligence/Machine Learning; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective of this topic is to research, develop, integrate, and test various models/algorithms for personnel recovery and/or isolated personnel evasion. Personnel recovery goal – given a last known location or area of interest, reduce the search space to find an isolated person. Evasion goal – given warfighter position and potentially a target evacuation zone (or zones), plan a route that allows the warfighter to evade capture and get to a safe area. The solutions sought should: take into consideration additional information, attempt to model personnel under different circumstances (injured, elderly, etc.), or be created with unique/novel Artificial Intelligence and/or Machine Learning-based approaches. The technology can be applicable to military environments as well as civilian search and rescue.

DESCRIPTION: Currently, the Joint Personnel Recovery Agency utilizes various tools (LandSAR, OSPPRE, FINDER) to 1) narrow a search space to find lost/isolated personnel and 2) allow isolated personnel to plan evasion routes. These technologies utilize terrain data, land cover data, points of interest, etc. to determine the best route for evasion or the most likely area that a lost person may be located. Each of these tools could be supplemented with additional models/approaches. The framework for integrating these approaches is under ongoing development; the main request is to integrate new approaches into that framework.

PHASE I: Conduct a study to understand personnel actions in various settings when lost AND/OR how they should best act when evading hostile forces, ensuring developed algorithms will accurately align with what can be expected in a real-life scenario. Survey the types and formats of data available for use for these algorithms including terrain, land cover, watershed data, etc. Develop a plan with the Technical Point of Contact (TPOC) for the environment to be used for testing and simulation. Develop a roadmap for phase II work.

PHASE II: Implement the roadmap developed in Phase I. Collect additional data if necessary. Develop the system and implement on relevant hardware (if applicable). Demonstrate capability and gather feedback from relevant end-users. Develop a plan for Phase III and dual use.

PHASE III DUAL USE APPLICATIONS: Successful/promising evasion algorithms could lead to additional Phase III work with the DoD or law-enforcement agencies to expand models to various situations and environments. For search and rescue algorithms, there is vast commercialization potential. Various humanitarian groups would utilize the technology for their search and rescue missions.

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KEYWORDS: Evasion; Personnel Recovery; Algorithms; Artificial Intelligence; Search and Rescue; Optimization; Planning

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AF221-0014 TITLE: Cross-Compatible Electronic Kneeboard Integration

TECH FOCUS AREAS: Network Command, Control and Communications; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Electronics; Information Systems; Battlespace

OBJECTIVE: This topic seeks to provide cross-compatible software between iOS flight planning and execution software and Tactical Assault Kit / Team Awareness Kit (TAK), thereby eliminating the need for pilots/aircrew to actively engage with two separate devices during mission execution.

DESCRIPTION: Air Combat Command (ACC) identified a need for the development of cross-compatible software between TAK and iOS devices. This proposed project would provide integration between native iOS apps used extensively by pilots for mission planning and execution to eliminate the need for aircrew to actively engage with two different devices (i.e., an iPad for flight apps and an Android tablet for ATAK). This functionality would allow pilots to interact with ground units without the added distraction of a second electronic kneeboard device.

PHASE I: In Phase I, this topic seeks to develop a plan for cross-compatible software that allows the TAK environment and native iOS apps to interact on the same electronic kneeboard device. This software must allow pilots to actively interact with both environments without the need for two separate devices. Program report must outline at least two methods for a cross-compatible electronic kneeboard solution and proved a detailed roadmap of the project objectives for phase II.

PHASE II: In Phase II, firms will develop and integrate cross-compatible solution on a single electronic kneeboard device. Initial prototype must demonstrate the ability to engage with native iOS applications and ATAK using one tablet. Prototype must be tested during a live exercise alongside existing system to demonstrate its capabilities and effectiveness. Integrate solution with the latest version of ATAK and establish procedure for regular updates.

PHASE III DUAL USE APPLICATIONS: Software has the potential to be utilized in government, commercial, and civilian applications. The final product would help bridge the gap between native iOS applications used extensively across the aviation community with the ground-based situational awareness features of TAK. Widespread use of the software would provide feedback to improve the integration of these two systems and allows avenues for continued improvement.

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KEYWORDS: Electronic Kneeboard; Flight Companion; Electronic flight bag; aerial situation awareness; ADS-B

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AF221-0015 TITLE: Fast Prediction of Human Safety Due to RF Exposure

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: This topic seeks to design, develop, and test fast, automated tools for predicting safety of humans in Radiofrequency (RF) exposure environments for integration into DoD modeling, simulation, and analysis frameworks such as advanced framework for simulation, integration, and modeling (AFSIM). Technology approaches may take advantage of existing machine learning tools (e.g., Varied Interface & Phenomenology Engineering Relationship Suite Relationship Suite (VIPERS), TensorFlow), and existing software end-to-end frameworks (e.g., the Galaxy framework).

DESCRIPTION: The government has access to a suite of tools for simulating the human body's thermal response to radio frequency (RF) exposure from nearby electronic equipment, radar, and other RF devices, with a focus on the safety of soldiers in these scenarios. Separate tools also exist for analysis of laser-tissue interaction at the physics-level. These tools are not currently integrated with mission-level applications such as AFSIM; however, the VIPERS tool, for example, enables AFSIM to directly drive arbitrary surrogate models. VIPERS also provides a linkage to Galaxy, which can be used to drive the physics simulations that produce data for the surrogate models. Therefore, while it is not necessary to integrate the thermal modeling tools with AFSIM, it is crucial that the thermal modeling workflows can be automated from frameworks such as Galaxy to be run on DoD clusters to produce input data for surrogates. Unfortunately, the process of combining physics-level thermal tools with machine learning applications and end-to-end simulation frameworks currently requires an analyst in the loop. These main-in-the-loop pieces include armature registration and posing for RF analysis of whole-body models, and uncertainty quantification across broad parameter spaces for RF and laser-tissue interactions. The government is interested in methodologies and implementations that will enable full automation of the thermal simulation workflow across whole populations of virtual humans, poses, and exposure scenarios. Current human body simulations can predict whole body energy deposition from microwave exposures at a 2-millimeter resolution in 10s of minutes, and large uncertainty quantification runs of RF and laser-tissue interaction may take days on high performance computing clusters. In order to be appropriate for use in DoD MS&A environments, quasi-real time operation (10s of seconds) of the developed surrogate models is desired, which should include the output of confidence intervals from the surrogate model simulations.

PHASE I: Offerors should propose design methods for implementing existing tools for simulating the human body's thermal response to RF and laser exposure in quasi real-time (a >= 60x increase in execution speed). Methods should predict core and local temperature changes as a function of time, beam parameters, and body position. Method should also provide a measure of uncertainty quantification for the results.

PHASE II: Phase II efforts will implement and deliver code to execute on DoD computing clusters. Accurate and quasi-real time performance on whole body thermal response to RF exposure will be demonstrated.

PHASE III DUAL USE APPLICATIONS: Military applications include engagement modeling and simulation, risk assessment, and occupational health evaluations. Civilian applications include real time prediction of risks from RF occupational exposure.

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KEYWORDS: Computation models; RF exposure; modeling environments

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AF221-0016 TITLE: IoT testing and Experimentation for End-to-End Scenarios

TECH FOCUS AREAS: Cybersecurity; Network Command, Control and Communications; Autonomy; Artificial Intelligence/Machine Learning; 5G

TECHNOLOGY AREAS: Sensors; Information Systems

OBJECTIVE: This topic seeks to establish the tools and processes, and best practices for integrating and testing real and simulated IoT edge devices and telemetry in the context of digital twins defined for testing and evaluation of Air Force mission use cases.

DESCRIPTION: Efforts will develop an IoT test environment for modeling end-to-end solutions for mission-centric scenarios. This will be accomplished by leveraging a cloud-centric ecosystem for developing processes and methodology for end-to-end IoT testing and evaluation of AF mission-centric scenarios.

PHASE I: Phase I will establish a methodology around a flexible ecosystem of tools to enable digital twins modeling, data analytics and data management capabilities. Internet of Things/Internet of Battlefield Things (IoT/IoBT) implementations are proliferating across Air Force Installations of the future, offering improvements in efficiency, readiness and situational awareness. At the same time, this technology also presents new attack vectors for potential adversaries. A flexible and modular data architecture is required to thoroughly test and evaluate IoT technologies, as well as to support operational use cases. The Phase I concept development will consist of an initial capability description including a baseline testbed architecture, a cloud-centric data management concept description, and a description of a flexible ecosystem of tools to enable digital twin modeling, data analytics and data management. Phase 1 will provide foundational artifacts that will lead to a Phase 2 prototype.

PHASE II: Based on the results of Phase 1, develop and demonstrate an initial framework, a detailed architecture design, and a cloud-based digital twin IoT testing prototype ecosystem. The framework will describe all capabilities required to perform IoT modeling, simulation and testing for Air Force system application. The ecosystem shall include a multi-layer architecture to effectively collect, process, analyze and store data collected by IoT/IoBT devices to drive operational technology and/or inform command-level decision making. Phase 2 will additionally involve collaboration with AFRL engineers/AF community to establish mission-centric use cases to demonstrate and evaluate the digital twin's prototyped architecture's ability to support next generation Air Force mission scenarios.

PHASE III DUAL USE APPLICATIONS: Work with the DoD to demonstrate the use-cases and exemplars developed during Phase II are applicable to DoD systems and software. Further demonstrate and deploy the capability within diverse environments.

Potential PH III military applications
1. Smart base digital twins (such as Tyndall) would utilize the proposed capability to model the base before acquisition of IoT hardware, devices, and IT support.
2. UAS digital twins would be a low-cost method of testing autonomous vehicles before actual flight.
3. Use of data analytics and data modeling when preparing for theater-level events

Potential commercial applications of this technology:

1. Using the developed processes and methodology to efficiently model and plan a manufacturing factory that will utilize IoT devices and communication within the factory and the cloud. This will ensure all devices send correct data and as efficiently as possible. In addition, the security of the devices would be modeled and analyzed to ensure safety.
2. Any product that utilizes IoT devices/sensors (e.g., vehicles, homes, medical equipment) can be represented by a digital twin model in order to discover any problems before prior to development. The proposed capability would be useful for both military and non-military (commercial, medical, manufacturing, etc.) applications.

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KEYWORDS: IoT; methodology; Digital Twin; best practices; modeling

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AF221-0017 TITLE: Development of a High-Fidelity DoD 5th Percentile Female Finite Element Model

TECH FOCUS AREAS: Biotechnology Space

TECHNOLOGY AREAS: Bio Medical; Air Platform

OBJECTIVE: This topic will focus on development and validation of a high-fidelity DoD-defined 5th percentile female finite element human body model for use in the evaluation of aircraft safety system performance and injury prediction during high dynamic loading events.

DESCRIPTION: The Airworthiness process for aircraft safety systems and aircrew flight equipment safety evaluations requires data specific to the likelihood of injury of both large male and small female occupants. Historic methods for acquiring these data includes the use of USAF-modified hybrid III manikins undergoing a series of specific high dynamic loading events while collecting data on the manikin response for evaluation. Not only is the required testing extremely costly but the facilities required to perform the tests are few, resulting in difficulties meeting program schedules and ultimately a delay in providing capabilities to the warfighter. Advancements in finite element modeling and the ability to accurately model human interaction within environments has led to an increased use of such methods during the development process of various system types. The most complex of these models utilize magnetic resonance imaging (MRI) and computerized tomography (CT) imaging techniques to develop subject specific computer aided design (CAD) geometries of all major organs, bones and subject musculature. From these high-fidelity CAD models, finite element meshes are derived and individual components combined using various techniques to create the detailed human body model. Consisting of upwards of 3 million nodes and elements, these models are capable of providing insight into things from lower extremity fractures to head injuries and many things in between. The primary driver for the development of these models for safety evaluations, however, is the automotive industry, and with differing loading cases as well as certification criteria, there are still gaps if these are to be utilized for aircraft development. Mainly, the primary focus for human body model development thus far has been on high fidelity 50th percentile male models. While there have been small efforts looking into female human body model development as well as morphing existing 50th percentile male models to various anthropometries (5th through 95th percentile males), there has not been an extensive effort to directly generate a high-fidelity DoD defined 5th percentile female (103 lbs, Joint Primary Aircraft Training System Case 7 anthropometry) model and validate that model for aerospace level loading in the Gx, Gy and Gz directions. Not only would the development of such a model aide in the development and evaluation of new aircrew flight equipment and safety systems by reducing the cost and time required for certification, but it also directly supports the current Air Force Acquisition (SAF/AQ) initiative for digital engineering, the Biomedical and Air Platform Technology Areas, as well as the Biotechnology Technology Focus area.

PHASE I: For the Phase I effort, contractors shall develop and execute a plan for establishing end user requirements and develop a proof-of-concept model to illustrate functionality. The proof-of-concept model should incorporate geometries generated directly from a DoD defined 5th percentile female human body. The level of detail desired in the model should be determined through discussion with the end user and any simplifications to tissue morphology, interactions and/or connections should be agreed upon before implementation in the model. The model should demonstrate realistic joint motions, hard/soft tissue connections and tissue response in end user specified loading scenarios. Validated material properties shall be used for all materials being modeled as defined in related literature. At the conclusion of the effort, a functional version of the model shall be delivered to the end user along with a perpetual license for operation, if required.

PHASE II: Contractors awarded a Phase II shall mature their 5th percentile female human body model to include active musculature throughout and validate the model response against human subject and cadaver data for both the active and passive muscle states, respectively. Requirements for validation should be discussed with the end user and the data utilized for comparison agreed upon. The model should demonstrate the ability to accurately predict gross kinematic response during defined loading events such as aircraft hard landings, crash and occupant ejections. The model should also provide the ability to further investigate localized forces/moments and accelerations in regions of interest defined by the end user and the ability to utilize that data in the injury predictions equations provided by the USAF. The environment chosen to house the model shall contain a graphical user interface (GUI) that allows for quickly modifying model position to adjust for different seated and standing postures. The model shall also contain the ability to incorporate interactions with external structures, such as aircraft crew member seats and/or ejection seats. At the conclusion of the effort, a validated, functional 5th percentile female model with active and passive musculature along with a GUI to enable model re-posturing/repositioning shall be delivered to the end user along with a perpetual license for model operation, if required.

PHASE III DUAL USE APPLICATIONS: Phase III awardees shall build upon their Phase II 5th percentile female model to expand model fidelity and functionality. The GUI shall also be expanded to allow for easy creation of critical aircrew restraint systems, such as standard aircrew harnesses and lap belts, as well as modifications to the occupant environment. The final deliverable will contain a validated 5th percentile female finite element model with the ability to model active and passive musculature. A supported GUI will be provided to enable easy re-posturing of the model as well as generation of restraint systems and additional structures, such as seats and standard aircrew flight equipment of interest, to include aircrew helmets and helmet mounted displays. Typical scenarios agreed upon by the contractor and end user shall be pre-programmed into the GUI for quick setup and/or the appropriate setup files provided for an equivalent ease of use. At the conclusion of the effort, a functional version of the model shall be delivered to the end user along with a perpetual license for operation, if required. This capability will provide the ability to evaluate the injury potential for high dynamic loading scenarios specific to small female occupants for use in evaluating new aircraft safety system design, aircrew flight equipment design, as well as existing safety system modifications. Potential avenues for transition include Air Force, Navy and Army Aircraft Program Offices for use in Safe-to-Fly evaluations as well as any commercial air and spacecraft manufacturers that have requirements related crash safety standards for certification.

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KEYWORDS: finite element modeling; human body modeling; 5th percentile female; crash safety; aircraft ejection; head injury; neck injury; spine injury; ejection injury

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AF221-0018 TITLE: A Closed-Loop Sense/Assess/Augment Wearable Device for Autonomous Performance Enhancement

TECH FOCUS AREAS: Biotechnology Space

TECHNOLOGY AREAS: Bio Medical; Sensors

OBJECTIVE: This topic seeks to develop a closed-loop wearable system to continuously measure a subject's performance indicators, identify performance decay episodes, and deliver, in a controlled and automated manner, enhancement agents to return the subject's performance to optimal levels.

DESCRIPTION: Missions in remote locations, including U.S. Africa Command (AFRICOM), require service members to operate with minimal on-site support for extended durations. Operations in these locations often demand that "go or no-go" decisions be made with limited situational awareness regarding the risks to service members. Emerging technologies that enable assessment of their physical and mental state can greatly inform upon those decisions, leading to better command and control (C2) decision-making that reduces the potential for loss of life and mission failure, as recommended in the Air Force S&T 2030 strategy, "demands on combat decision-makers are outstripping the cognitive capacity of the unaided human". Moreover, technologies capable of automated assessment can augment force readiness with minimum embedded medical support. A significant body of work has been devoted to the design of systems to monitor neurochemicals in the brain for closed-loop neuromodulation to address conditions including Parkinson's disease and other medical conditions. Along the same lines, the concept of an artificial pancreas is based on the availability of the continuous glucose monitoring and the ability to use its data to control the delivery of insulin through an external pump. Less attention has been placed on closed-loop systems for non-medical conditions, including stress and fatigue, which critically affect performance in the field. Recent work has demonstrated that electrochemical aptamer-based sensors can be used for feedback-controlled drug delivery of an antibiotic, providing an opportunity to expand the development of these closed-loop systems to other molecular targets using a variety of sensor architectures. The aim of this topic is to demonstrate new capabilities in the bio medical and sensors technology areas consisting of a wearable sensor that can monitor personalized performance indicators. The sensor should assess the information and autonomously initiate delivery of the performance enhancement agent(s) when performance decay is detected, until the metrics evaluated return to pre-intervention values. This technology will provide capabilities to restore service members operating in austere environments back to full capacity, addressing needs in the focus area of biotechnology.

PHASE I: Phase I firms will perform a literature search to determine the ideal prototype architecture to demonstrate a closed-loop sense/assess/augment capability and identify the appropriate molecular performance biomarkers to be monitored by the device and the enhancement agents to be delivered. Based on these studies, develop a product development project plan adapting existing technology as much as possible or developing a new platform, if necessary. Efforts will define a use case, expected benefits, development milestones, and schedule for a Phase II prototype, as well as identifying key risk areas and associated mitigations. Performers will engage with and support USAF sponsors and partners to develop concepts of operation.

PHASE II: Companies selected for Phase II will execute the plan designed in Phase I. Development should include validation of performance in a representative environment for both intermediate and final system prototype deliverables. Efforts will demonstrate the performance of final prototype system by measuring stress-related biomarkers, assessing a subject's stress levels based on biomarkers and delivering enhancement chemicals when stress adversely affects performance in a realistic or actual environment of intended use. User interface functionality will be demonstrated, and an integration pathway defined to make data available for decision actions. This will require engagement with USAF sponsor and end-user representatives to guide development and test and evaluation strategy.

PHASE III DUAL USE APPLICATIONS: The "artificial pancreas" is a recent product realizing the concept of a closed-loop system for a non-neuromodulation application. Recent advances in Academia have demonstrated it is possible to expand these capabilities beyond glucose/insulin. The performer could look into the medical field for dual-use opportunities for the closed-loop sensors to be developed. For instance, these types of systems could be applied to the care of patients in emergency units by providing pain medicine as well as antibiotics, only when needed and until the patient does not need this intervention any longer, which would dramatically decrease the workload of first responders and care professionals.

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KEYWORDS: closed-loop system; drug delivery; sensors; stress; performance recovery

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AF221-0019 TITLE: Novel Techniques for Gas Turbine Engine Bearing Inspection

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Materials; Air Platform

OBJECTIVE: This topic seeks to develop a novel strategy to reduce the cost and time to inspect Silicon Nitride (Si3N4) bearing rolling elements. Concepts focus to reduce the cost and inspection time of conventional non-destructive inspection (NDI) by a margin of 30% while maintaining the current standard of inspection. The strategy should accommodate multiple sizes of rolling elements, and accommodate both rollers and ball designs.

DESCRIPTION: Turbine engines utilize Si3N4 rolling element bearings within the engine. Si3N4 has become the material of choice for rolling elements in turbine engine bearings due to its ability to withstand high loads, reduce frictional heat generation in the bearing contact, and reduce overall component weight. The proliferation of Si3N4 rolling elements in all bearing locations both in the main shaft bearings and in gearbox support bearings places more importance on both the accuracy and expedience of inspection methods. The strategy should accommodate multiple sizes of rolling elements and accommodate both rollers and ball designs.

PHASE I: Phase I efforts will show the feasibility for a novel concept or new method to NDI Si3N4 rolling elements. Develop a design/test strategy for evaluating the ideas and identifying the key performance parameters necessary to document ability to meet the minimum flaw size and probability of inspection requirements utilizing assets owned by AFRL. Selected companies will also develop an initial transition and business plan.

PHASE II: In Phase II, the methodology developed in Phase I should be validated for additional conditions replicating 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 new inspection method into a production facility. The work should be transitioned to interested OEMs and/or bearing suppliers.

PHASE III DUAL USE APPLICATIONS: Si3N4 has become the material of choice for rolling elements in turbine engine bearings for advanced military engines. Recently, this material has been implemented into large commercial engines due to the beneficial weight savings as well as improved resistance to wear and fatigue relative to metallic rolling elements. Improved inspection technologies under this effort will have a direct impact on commercial airline operators by reducing both part cost and lead time for main-shaft bearings.

REFERENCES:

1. ASTM 1417 “Standard Practice for Liquid Penetrant Testing”; ASTM 165 “Standard Practice for Liquid Penetrant Testing for General Industry”

KEYWORDS: non-destructive inspection; silicon nitride; ceramic; rolling element bearing; rolling elements; ball bearing

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AF221-0020 TITLE: Thermal Control Techs for High Performance, Resilient SmallSats

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: This topic seeks to provide next-generation thermal control technology to enable high performance, resilient small satellites for the hybrid space architecture. Technologies must be leveraged to reduce spacecraft overall size, weight, power, cost, and operational constraints and increase spacecraft overall reliability, capability, and operational agility.

DESCRIPTION: Thermal technologies are required on every spacecraft and their resource demand (size, weight, power, etc.) cause them to be design-drivers for the overall spacecraft. The current push toward SmallSats, alongside the ever-present need to manage higher electronics heat fluxes, creates a need for a new generation of thermal control technologies. This topic solicits novel thermal technologies to address a variety of pressing needs in the electronics Thermal Stackup. Technologies of interest are: 1. High thermal conductance die attach materials – must function in space electronics environment 2. Heat spreaders for High Heat flux electronics (such as GaN and laser diodes) including for Transmit/Receive modules 3. Digital electronics (e.g., ASIC, FPGA) thermal straps – much higher thermal conductance than standard conductive thermal straps, a passive convective solution is anticipated 4. High thermal conductance electronics cards heat sinks – again, a passive convective solution is anticipated 5. Reworkable thermal interface materials for electronics units 6. SmallSat deployable radiators – mass and cost competitive thermal radiators ranging from 0.5ft2 to 15 ft2 7. Autoregulating thermal radiator coatings – strike a balance between performance and operation in the space environment 8. Spacecraft materials resistant to directed energy (DE) – either purpose-built shields or materials incorporating shielding as a secondary capability 9. Pulsed power thermal energy storage – novel phase change materials that have realistic operation (enough useful life, non-corrosive, etc) 10. Self-regulating heaters – for use on propellant lines and other bus components, design for the space environment 11. Battery thermal control for CubeSats & SmallSats – provide better isothermality to enhance life 12. Cryogenic thermal control technologies with no-moving-parts – seeking simpler designs yielding enhanced reliability, no induced vibe, savings of size, weight, and cost; consideration of system-wide concept-of-operation impacts required 13. On-orbit robotically mated/demated conductive thermal interfaces Offerors should emphasize understanding of the relevant space and spacecraft environments in planning the research of the proposed technologies. Space environments include thermal cycling, microgravity, ionizing radiation, launch vibration, vacuum, and more. Spacecraft environments include all of the competing constraints of various components and subsystems. Offerors must demonstrate that their technology does not invalidate the use of other incumbent technologies functioning as part of other subsystems. Actively pumped systems are highly unreliable, heavy, and expensive and are thus strongly discouraged. Passively driven convective systems (e.g., heat pipes, vapor chambers) are encouraged.

PHASE I: Phase I proposals should define requirements to survive and perform with intended space and spacecraft environments. Engagement with spacecraft prime integrators or 2nd tier integrators is encouraged. Analyze technologies' capability to meet thermal subsystem needs in the context of USSF spacecraft. Offerors should highlight how studies will transition to follow on physical hardware tests or how benchtopt demonstrations will scale up to more representative demos in later phases.

PHASE II: If selected for Phase II, companies will design, analyze, build, and ground test the technology, showing capability to survive and perform in the space and spacecraft environment. If possible, space qualification testing should be performed such that the offeror is prepared to sell the product to the space market at the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Phase III effort will design, build, and deliver a flight experiment to demonstrate the technology in the space environment.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: Thermal Control Subsystem; Space; Thermal; Thermal Interface Materials; Heat Pipes; Oscillating Heat Pipes; Deployable Radiators; Phase Change Materials; Variable Emissivity Materials; Smart Heaters; DE Hardening; Passive Cryogenics

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AF221-0021 TITLE: Landing Area and Rocket Plume Diagnostics

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Landing on unimproved, irregular surfaces will be required for Rocket Cargo and would enable many missions supporting Tactically Responsive Space Access. Little information is available on the interaction of a plume and different types of surfaces. Additionally, necessary data for anchoring and improving models is unavailable. The objective of this topic is to develop diagnostics capable of measuring velocity and/or structures involved in plume-ground interactions. Solutions will be demonstrated at the 1 klb thrust scale, and attention should be given to scale limitations.

DESCRIPTION: Although vertically landing a rocket on an improved, flat surface has been achieved by multiple launch vehicle companies (Masten Space, SpaceX, Blue Origin) [for example, 1], landing a rocket vehicle on an irregular, unimproved surface has a number of challenges including, but not limited to the plume kicking up dust and creating an observable event and erosion of the surface leading to a crater and/or rocket instability. The terrain the rocket vehicle may land on is not known a priori and may vary widely. Plume-ground interactions must be sufficiently understood to make decisions on acceptable landing sites and to provide necessary mitigations to enable the use of initially unsuitable sites. Additionally, information on what happens to eddies and heat after the ground stagnation point are required to determine safe stand-off distances for equipment, ensuring they are not impacted by debris (e.g., rocks) nor experience unacceptable temperatures. This information on interactions will additionally aid rockets operated for commercial applications since many companies are focused on landing and reusing their rockets, and the data can be used to inform decisions on manufacturing landing pads. Some information on plume-ground interaction is available from landing on improved surfaces and from NASA investigations of extraplanetary landing [2]. Such data is of limited scope and fidelity, however. Small-scale studies of plume-ground (simulant) interactions are of interest due to the increased fidelity available. Both improved surface landings and small-scale experiments have demonstrated the ability to obtain temperature and heat flux profiles on the ground. However, structures within the plume, including their interaction with the ground and evolution thereafter, are not yet available. Similarly, velocities within the plume are unattainable. These metrics are crucial for assessing surface survivability, stand-off distances for personnel and critical ground equipment, and for developing accurate computational models. However, they are difficult to acquire due to the large luminosity of the plume, density gradients within the plume, and, to a lesser extent, general size scales involved. For example, traditional and even next-generation Particle Image Velocimetry can only provide near-surface data due to the luminosity of the plume overcoming that of embedded particles [3, 4], and introduction of particles, especially not eroding the chamber throat, can be problematic and difficult. NASA’s HiDyRS-X project was able to overcome the luminosity challenges but had limitations with temporal resolution making evolution studies difficult or impossible [5]. This topic seeks solutions which enable visualization of large structures and their interactions with the ground and/or the quantification of velocities within the plume before and after interaction with the ground. Temporal resolution must be sufficient to understand evolution as the plume contacts the landing site. To meet necessary acceleration of technology development and the demands of high-fidelity CFD, the methods must provide two- or three-dimensional data. Methods will be demonstrated on a small-scale, 1 klb thrust, kerosene-oxygen rocket chamber during Phase II. AFRL/RQRC will provide one week of testing time, up to ten tests a day, and the rocket chamber and ground simulant to carry out such a demonstration. AFRL/RQRC will also provide up to two black-and-white, high-speed cameras (Vision

Research Phantom) as necessary. Proposals should consider limitations for applications on larger rockets including a scale at which they would be untenable due to luminosity, size, or other complexity. Resolution and/or uncertainty estimates, as applicable to the measurement, should also be included.

PHASE I: Selected companies will establish the method overcoming complexities related to plumes. Verification can be a combination of reduced-scale demonstration (e.g., within bunsen-burner flame) and analysis. This verification, however established, will be documented and delivered as part of the Phase I work and will provide confidence that the system can be used successfully to collect data from a small-scale plume. Efforts should also quantify resolution and/or uncertainty of method, which will be documented as a deliverable. Companies will interact with CFD model developers to ensure needs are met. Data collected as part of verification will be provided to model developers as well as sufficient information regarding experimental set-up to allow data use in testing models.

PHASE II: If selected, companies will deliver necessary software and hardware prototype package to AFRL. Efforts will demonstrate the diagnostic technique with a 1 klbf, kerosene-oxygen engine plume impinging on a landing pad simulator. AFRL/RQRC will provide hot-fire testing with their 500-1000 lb thrust stand for such demonstrations, or an equivalent or larger system shall be used. Operation of the diagnostic will be shown across mixture ratios from 2.2 to 2.8 (at a minimum). Landing pad simulator will be located at a range of distances to be determined, but within the overall range of 18-72 inches. Air Force will be provided data package from demonstration to CFD modelers.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will scale the diagnostic to a 10 klbf thrust engine or larger and provide demonstration of efficacy and/or field prototype system for demonstration with medium or large rocket landing (to include dust and other environmental factors). This demonstration will necessarily involve commercial partners since the military does not manufacture nor purchase rockets.

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5. Revolutionary Camera Recording Propulsion Data Completes Groundbreaking Test, https://www.nasa.gov/feature/revolutionary-camera-recording-propulsion-data-completes-groundbreaking-test

KEYWORDS: rockets; plumes; plume-ground interaction; plume-pad interaction; diagnostics

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AF221-0022 TITLE: Explainable AI (XAI) for RF Applications of Deep Learning

TECH FOCUS AREAS: Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Sensors; Information Systems

OBJECTIVE: This topic seeks to develop new approaches to explainable AI (XAI) applicable to advanced radio frequency (RF) applications such as radar, electronic warfare (EW), ELINT and SIGINT. This would allow for adequate testing and evaluation (T&E) of deep learning networks (DLNs).

DESCRIPTION: The recent successes of deep learning applied to a variety of complex RF applications such as cognitive radar (CR) has prompted the need for new T&E methods to validate both performance and reliability, particularly for DoD applications. Explainable AI (XAI) is a branch of research focused on understanding "how and why" a DLN arrived at the response it did. However, for DoD applications, a very rigorous level of validation and reliability must be achieved in order to declare a system "operational". Thus, new XAI methods for DoD-specific applications are required that statistically: (1) quantify performance in an operationally relevant environment: and (2) quantify reliability (and thus availability). Methods are sought that do not require extensive (and expensive) field testing to obtain the relevant statistics.

PHASE I: Phase I efforts will pursue new XAI methods specifically addressing the DoD's needs for rigorous T&E to declare a warfighting system operational. In particular, rigorous XAI approaches are sought that can result in accurate statistical characterizations of both performance and reliability. These approaches should also minimize reliance on costly field experiments or testing. The feasibility of the proposed methods should be established in Phase I via a combination of analysis and computer simulation. Phase I should end with a clear technology development and transition roadmap for Phase II and beyond.

PHASE II: In Phase II, the methods developed in Phase I should be further developed and matured. One or more real-world focus applications will be selected to serve as the pathfinder for the new XAI approaches. Details of the new XAI procedures shall be delineated in a manner sufficient to transition to established DoD T&E organizations. The output of Phase II should be mature enough to enter low-rate initial production (LRIP) in Phase III.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will identify potential commercial and dual use applications. It is expected the inherent utility of the new XAI methods will be of immediate value to all commercial enterprises, incorporating advanced DL methods.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: Artificial Intelligence; Explainable AI; Deep Learning; Cognitive Systems; RF modeling and simulation;

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AF221-0023 TITLE: Energy Deposition Systems for Scramjet Engine Ignition and Combustion Augmentation

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: This topic seeks to develop energy deposition technologies for scramjet ignition and combustion augmentation using only on-board vehicle resources (e.g., vehicle fuel, air, and electrical power).

DESCRIPTION: The U.S. Air Force has invested in scramjet ignition technologies from both a fundamental [1–4] and applied perspective. Specifically, focus has been on Insensitive Munitions compliant ignition systems for missile platforms, which has allowed for accelerant-type systems to be used, such as pyrophorics/hypergolics, alternative oxidizers, etc., as well as consumables, such as compressed fuels or oxidizers. While many of these systems are suitable for packaging and application to expendable hypersonic systems, some are not ideal for reusable hypersonic platforms. In addition, moving away from systems with accelerants and other consumables would reduce the complexity in expendable systems. Therefore, there remains a desire to develop/mature scramjet ignition systems that only use on-board resources, such as the vehicle fuel (e.g., JP or RP-type), air, and electrical power. In addition to ignition, there is a desire to augment combustion processes in scramjet engines via energy deposition. By strategically depositing energy within an engine, combustion can be accelerated, therefore enhancing overall engine performance during off-design conditions. These “combustion enhancement” technologies also need to only use on-board vehicle resources but have the additional constraint of high duty cycle or continuous operation during certain portions of a flight profile. This topic seeks to produce new or mature existing energy deposition methods for scramjet ignition and combustion augmentation only using vehicle fuel and/or air and/or electrical power. It is envisioned the developed energy deposition technologies may be suitable for ignition or combustion augmentation, but do not have to be applicable to both because of the different operational requirements set. Specifically, ignition systems typically require operation for short duration (or order milliseconds to seconds) and should be focused on the spatial extent of influence from the electrical and/or chemical energy deposition. Combustion augmentation systems require long duration operation and, therefore careful considerations of power efficiency, thermal management, and repeated cycling. Specific focus on the applicable technology development should be placed in the areas of power and fluid requirements, as well as the spatial and temporal distribution of electrical and/or chemical energy. The energy deposition devices should try to avoid physical protrusions from the wall where it is expected to be inserted within a combustor (either in the subsonic flame holder region or in supersonic flow). Experience has shown protruding devices have limited cycle/lifetimes. Rather, it is desired any developed devices can either deposit the electrical and/or chemical energy in a large volume near the wall, or project it away from the wall by fluidic or other means. The larger the volume/region that the energy can be deposited, the greater chance of ignition success or combustion augmentation. If the developed systems are successful, the government may choose to test in relevant scramjet environments. The effort will culminate in an energy deposition system for hypersonic platforms that uses no consumables beyond the fuel and electrical power already on-board a vehicle and bleed and/or ram air. Proposals detailing systems that require/store additional fluids will not be considered.

PHASE I: Selected efforts will conceive and develop energy deposition technology and show capabilities versus baseline spark discharge systems, typically localized energy deposition of order of several Joules with specific parameters provided after award. The device requirements of power/energy, fuel and/or air pressure and flow rates, volume and mass packaging constraints, as well as the spatial and temporal distribution of the energy from the device need to be well documented. Phase I deliverables will include a final report containing the preliminary system design, estimated performance results, scaling to different device size or energy output, and/or proof-of-concept of the device operation.

PHASE II: Companies selected for Phase II will complete development of the energy deposition technology and perform bench testing of the system to demonstrate performance results. If successful, application and demonstration in a relevant scramjet environment at a government facility is desired depending upon testing availability and priority. Focus should be on validation of the system in harsh environments experienced by hypersonic vehicles and packaging to meet power, volume, and mass constraints. Phase II deliverables will include the energy deposition system and a final report that documents the demonstration results.

PHASE III DUAL USE APPLICATIONS: Phase III efforts would optimize the design of the energy deposition system for application to different engine types (reusable or expendable), different engine scales, or mission profiles. It would also involve performing engine testing of the packaged system in relevant scramjet environments to validate performance.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: scramjet ignition; turbine-based combined cycle; missile; hypersonic; ignition; combustion; air-breathing propulsion

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AF221-0024 TITLE: Innovative Concepts for Runtime Assurance Technologies

TECH FOCUS AREAS: Autonomy

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The concept of runtime assurance (RTA) was first introduced in the 1990s and has been studied, developed, and applied to several specific systems since that time. However, if RTA applications are to be expanded for more operational uses and fielded in a wider range of platforms and systems (i.e., beyond R&D and flight-testing stages), then a number of technical hurdles will need to be addressed. Past and current R&D efforts in RTA have and are being conducted by both NASA and the Air Force Research Laboratory (AFRL). The near-term objective of this topic is to invest basic and applied research to build on accomplished R&D, address specific identified technical challenges, advance specific RTA design applications, and develop general design methods and approaches applicable to future Air Force, DoD and commercial systems. Far term objectives involve advanced technology development to construct RTA avionics packages, perform real-time hardware and flight testing of the RTA products, accomplish full V&V and certification of their intended uses, and manufacture and field the developed RTA systems in specific Air Force, DoD and commercial platforms.

DESCRIPTION: To address future Air Force strategic needs, an increasing number of advanced systems with intelligent autonomy are being envisioned. Intelligent autonomy is central to systems involving advanced automation, artificial intelligence, machine learning, and a wide range of intelligent adaptation, reconfiguration and autonomous decision making. However, a critical roadblock to the implementation and ultimate fielding of such systems are the required assurances that these advanced functions will always do the right thing. Advances in formal methods give new tools for design-time verification & validation (V&V) of these cutting-edge concepts. Yet, it is widely recognized that RTA will also be a necessary part of the overall solution towards trusted systems. This topic addresses the need for new approaches to realize implementation of RTA systems. RTA provides protection from errors in advanced functions not discovered during design-time V&V by 1) continually monitoring critical system states and parameters, 2) determining whether the system is safe and operating correctly, 3) if not, switching to a trusted, albeit less capable reversionary/backup function, and 4) allowing the reversionary system to recover to a safe/correct condition. The determination in step 2) is usually performed by observing if one or more system states have violated pre-defined boundaries. In general, this is denoted as the “switching condition” or the condition that determines when to switch to the reversionary/backup function. Original aerospace applications of RTA focused on protecting the inner-loop control and guidance systems from errors in advanced, adaptive controllers that could not be fully V&V’d to their required levels. However, there is now wide interest in expanding RTA applications to protect higher-level functions, including advanced intelligent-autonomy systems at the flight management and real-time mission planning/decision making functions in unmanned systems [1, 2]. There is also increasing interest in investigating how multiple interacting RTA systems should be designed for complex, multi-agent, distributed cyber-physical systems [3, 4]. Proposers can respond to one or more of the following sub-topics:

(1) Physics-Based Switching Condition Accuracy: Current fielded RTA systems have been beneficial for flight test research aircraft and have been termed “envelope protection systems,” employing physics-based switching condition boundaries (e.g., aerodynamic parameters, load factors, attitude rates, etc.). These research aircraft often perform iterative testing of experimental flight control code. At such design

stages, it is too time consuming and costly to perform extensive V&V analysis of this type of onboard code. However, the aircraft needs to remain safe during flight and if the human test pilot or remote operator cannot recognize an impending safety violation due to an error in the experimental code, the automated envelope protection system will detect the safety breach and immediately shut down the experiment, returning operation to the aircraft's production flight control system [5]. Current fielded RTA systems have also been beneficial for turbofan engine control. Engine protection systems monitor sensed physical states of the engine, such as fan and compressor speed, burner pressure and temperature, estimated surge margin, etc. If any of these parameters exceed their respective pre-defined bounds, then damage to the engine can occur or stable combustion lost. To prevent this, a reversionary fuel flow regulator takes over control of the engine and returns it to safe/stable operation [6]. Although beneficial, the envelope protection systems for flight test aircraft and the engine protection systems for turbofan controllers are broadly considered too conservative. Current allowable flight test operating envelopes are very restrictive to ensure safety of the pilots and aircraft, and the engine protection systems severely restrict the engine's transient performance. These systems are conservative because there are no practical methods to construct accurate physics-based switching conditions in an RTA system [5, 6]. Formal definitions of the switching condition boundaries that ensure safe operation were developed in [1]. However, these definitions involve complex control-theoretic conditions and do not provide realizable methods to construct the switching condition boundaries. For this reason, adding excessive safety margins seems to be the only current solution. For RTA to be broadly employed in operational applications, this problem needs to be solved. This need is not being currently addressed in NASA or AFRL R&D programs on RTA. This solicitation seeks proposals with innovative approaches to developing practical methods for the construction of accurate physics-based switching condition boundaries. Some approaches that could be considered are state reachability methods, targeted simulation methods, or other innovative, cutting-edge ideas. Successful outcomes would be demonstrated by reducing conservatism in currently fielded RTA systems, or in proving that advanced untrusted systems are allowed to operate throughout their defined envelopes as long as no software or design faults are detected. Performance should also be compared with baseline RTA methods that simply add additional safety margin to define the switching conditions.

(2) Integrated RTA – Monitoring for Both Hardware Failures and Software Errors: Another key enabling technology for advancing RTA operability is integration with hardware health monitoring and sensor redundancy management. This is related to the problem of information integrity. An RTA system that makes a decision to switch to its reversionary control function can do more harm than good if it is making that decision based on absent or incorrect information. An RTA system needs to know if observed anomalies are due to hardware malfunctions (e.g., control effector or sensor failures) or due to errors in the advanced system it is monitoring (due to software coding or algorithm design errors). The integration of RTA with hardware health monitoring has, to date, not been addressed. This solicitation seeks proposals that offer integrated software/hardware runtime assurance (integrated RTA) designs. Successful outcomes would demonstrate such integrated RTA systems, introducing seeded faults first in the advanced system's software, then seeded failures in control effectors and sensors. The integrated RTA system should respond appropriately in both cases, either shutting down the advanced system or allowing it to run, depending on the type of fault or failure determined. Comparisons should be made with RTA systems operating without hardware state knowledge showcasing the benefits of the integrated RTA approach.

(3) RTA Protection for Higher-Level Intelligent Autonomy in Complex Distributed Systems: Multiple interacting RTA functions within one platform have been studied in [1, 7]. It was determined that critical information needs to be passed between the interacting RTA modules involving current

operating conditions. Further, it was found that the complexity of the RTA designs grows rapidly with each introduction of another RTA protected module or subsystem. There is now wide interest in manned-unmanned teaming and other complex missions involving multiple unmanned agents operating in a cooperative command/control structure. Unmanned platforms possessing higher-level intelligent autonomy at the flight management or run-time mission planning levels will need RTA protection. This application of RTA is not currently being studied or addressed. Adding to the complexity of the problem, each platform will need to communicate with its neighboring fleetmates, negotiating tasks, deconflicting paths, etc., and coordinating current RTA operating states. For example, if one agent's RTA has switched to its less-capable reversionary flight management system, its lower-level performance could affect how it supports its fleetmates. This solicitation seeks proposals that offer design approaches and design considerations for RTA-protected platforms at the higher intelligent-autonomy levels involving functions that interact/communicate with teammates in a distributed, cooperative manner. The switching conditions of RTA systems at this level will not be checking physics-based criteria, but rather mission-based rules involving, for example, criteria that measure progress toward mission accomplishment, adherence of no-fly zones, optimality of teammate tasking, etc. Central to this effort will be to define/develop such mission-based RTA checks and to construct trusted reversionary flight management functions or procedures. Successful outcomes would demonstrate interacting RTA systems correctly keeping their ownships within defined operating parameters, and the team, as a whole, on course to successful mission completion. Reversionary operations should be demonstrated, including safe separation of a crippled vehicle from the fleet and its successful return to base.

(4) Other RTA Technology Advancements (General Topic): Proposals will also be considered that offer solutions to other technical hurdles, technology advancements or other innovative approaches that will broaden RTA application and improve RTA operability. Such topics include but are not limited to a) reversionary system design approaches that guarantee recovery anywhere in the operating envelope, b) approaches that reduce complexity in multiple, integrated RTA systems; b) improved approaches for design-time V&V and certification of RTA protected systems; c) integrated training of machine learning and other AI technologies with RTA switching conditions based on mission constraints.

PHASE I: In Phase I, focus should be on initial developments of proposed solutions to one or more of the aforementioned design challenges. Alternate solutions should be considered, and the most promising approaches identified. Feasibility studies should be conducted regarding proposed solution approaches. Initial design and analysis studies in desktop simulation environments should be performed. Based on initial analyses and experimental results, recommendations for further R&D and a Phase II technology development plan should be completed. Surrogate models representing Air Force platforms of interest can be used in Phase I. No government furnished data or equipment should be required. Air Force customers/stakeholders and specific Air Force technology applications of interest should be identified. These should be technologies in which advancements in RTA will provide significant benefit.

PHASE II: In Phase II, design details and experimental test plans should be significantly expanded. Development and analysis in higher fidelity desktop simulation environments with representative platform applications should be performed. Develop realistic use cases exercising RTA functionality and demonstrating benefits of RTA recovery processes. The RTA system should be agnostic of seeded faults in capstone demonstrations, proving its utility over a wide range of scenarios. Success will be defined by demonstrating the benefits of the advanced RTA technology as compared to current baseline RTA systems or platforms absent of RTA altogether. Develop real-time functionality and test/demonstrate the developed technologies in a software/hardware integration laboratory environment. Repeat some or all of the capstone experiments performed in desktop simulations. Cost and schedule permitting, port developed real time code to flight processors and perform initial flight demonstrations with surrogate sUAS platform(s), again testing capstone experiments. Depending on contractual arrangements, government furnished data or equipment could be provided in the form of simulation models or equipment supporting laboratory or flight testing. At this stage, systems used to demonstrate the developed RTA technologies should closely align with Air Force programs of interest that employ advanced, adaptive and intelligent autonomy. Technology transfer plans should be constructed showing how the developed Phase II products can directly support such programs in preparations for Phase III efforts.

PHASE III DUAL USE APPLICATIONS: In Phase III, teaming arrangements should be made with airframe/avionics manufacturers to develop/finalize RTA system design(s) in a pre-production phase. Required V&V, safety analysis and testing for eventual certification should be performed. Phase III activities should directly support Air Force programs of interest with flight testing and demonstrations on full scale vehicles. One such potential effort is the current Skyborg Vanguard program. This program is integrating autonomous UAV technology with open missions systems to enable manned-unmanned teaming. A successful Skyborg program will deliver a prototype suite of technologies to enable autonomous UAVs with enhanced capabilities for Air Force missions. However, trust in the autonomy will be paramount for close-in manned-unmanned operations and RTA will be a key enabling technology to provide the required level of trust in the unmanned systems. Another potential program is Agility Prime, which is developing transformative technologies for urban/advanced air mobility (UAM/AAM). These vehicles are incorporating non-traditional electric or hybrid propulsion vertical takeoff and landing capabilities (eVTOL/hVTOL). These aircraft are being developed for both manned and unmanned operations, typically utilizing a single onboard pilot, remote pilot, or fully autonomous control. Mission applications include personnel recovery/delivery, medical evacuation, resupply/distribution, patrol, search and rescue, etc. Here too, trust in the onboard autonomy will be critical. Often the onboard pilot will have limited flight training (e.g., an EMT or first responder). This, along with operations over densely populated urban areas will require significant evidence that the autonomy will be bounded to safe/correct actions. Again, RTA will be a key enabling technology to provide this evidence. Follow-on Phase III activities should expand applications to other branches of the military and DoD customers. RTA technologies are not limited to military applications and there is substantial potential to expand the developed products to commercial markets. Clear applications include civil/commercial uses of UAVs/UAMs with use cases in law enforcement, civil air patrol, firefighting, disaster/humanitarian relief, border patrol, bridge/building/utility inspections, environmental services, agriculture, etc. RTA applications should be extended to ground vehicles, self-driving cars, and other autonomous modes of transportation. Other applications may include industrial systems, medical devices, robotic applications and any functions requiring assured intelligent autonomy.

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KEYWORDS: Runtime Assurance; Verification and Validation; Certification; Safety Assurance; Assured Intelligent Autonomy

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AF221-0025 TITLE: Autonomous Sensing of Defense Tactical Targets by LEO Imaging Systems

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: This topic's objective is to develop machine learning (ML)-based analytic approaches and methods for autonomous detection and tracking of endo-atmospheric moving targets observed by EO/IR imaging sensors on LEO satellites.

DESCRIPTION: The DoD's intelligence, surveillance, and reconnaissance (ISR) enterprise seeks to bring to bear the tactical and strategic assets needed to detect, track, and target threats posed by potential adversaries. The development and integration of space-based, tactical ISR-enabling capabilities into a highly proliferated, hybrid space architecture is one critical element of employing the ISR enterprise for all-domain tactical operations. These capabilities are fundamental to ensuring that the ISR enterprise has timely and fully continuous tracking of tactical threats on a global scale in order to make warfighting decisions. One of the challenges to persistent ISR from space is having the sensing capabilities needed to collect and generate highly accurate indications of moving targets in order to convey timely actionable information across the integrated battlespace. In order to address this challenge and move beyond the current state-of-the art in detection, identification, and classification of mostly ground stationary targets, what is needed are transformative and disruptive technologies to outperform and re-conceive the function and operations of traditional space-based sensing systems and ground-based data processing, exploitation, and dissemination (PED) systems. One such transformative technology is autonomous space-based sensing for which this research topic seeks innovative autonomous data analytics that will enable highly agile sensing systems to create and deliver moving target information (MTI) as part of autonomous space architectures. The overarching goal and desired end state of this topic is an autonomous machine learning (ML)-based analytics architecture for autonomously detecting and tracking airborne moving tactical targets using MTI data that is derived from satellite EO/IR imagery and enables automatic and adaptive messaging and tasking of multi-domain assets. The objective of this research effort is to develop machine learning (ML)-based analytic approaches and computational methods for autonomous detection and tracking of endo-atmospheric moving targets observed by EO/IR imaging sensors on low earth orbit (LEO) satellites. This research effort specifically seeks to develop autonomous methods applicable to the generation of moving target information (MTI) for target flight profiles of varying altitude ranges and durations, including in-flight airborne vehicles.

The technology to be developed should focus on the need for innovative deep learning and other advanced ML methods that are not only automated and adaptive for surveillance of airborne tactical targets-of-interest from space, but also provide accurate and timely moving target information in the absence of large-scale data sets for model and algorithm training. Image simulation techniques that generate realistic training and test datasets containing moving target information are of interest, including data sets that are fully synthetic as well as those that are derived from real-world data. In addition, the research should focus on satellite imagery analytic capabilities needed for robust on-board and/or cloud-based autonomous sensing, including appropriate key performance parameters and metrics for evaluating the ability to correctly determine actual and predicted moving target information. Autonomous on-board analytics are of particular interest due to emerging data-intensive space-based sensing concepts and the need for real-time MTI. ML approaches are also sought for generating/sharing moving target information to defense messaging and tasking systems that are local/distributed, including at the edge, as part of autonomous sensing grids.

PHASE I: Companies selected for Phase I will conduct a review and assessment of candidate ML-based analytic approaches and computational methods for autonomously processing large amounts of space-based EO/IR imagery for moving target information (MTI). Investigate the feasibility of potential image simulation techniques and models for creating training and test data sets for autonomous data analytics. Efforts will evaluate the challenges of real-time implementations of autonomous analytics on spacecraft processors.

PHASE II: Phase II efforts will design, develop, and implement a prototype autonomous analytics architecture for generating moving target information (MTI) using ML-based and other advanced data processing methods. They will demonstrate prototype architecture's autonomous functionality and operation using synthetically created data sets of LEO EO/IR imagery of in-flight aircraft and other militarily relevant targets over full flight profiles and trajectories. Additionally, demonstrations will be conducted on spacecraft processors, cloud-based platforms, and/or PC-platforms and assess trade-offs for different computational hardware with respect to MTI accuracy and latency. The demonstration's performance of the emulated autonomous end-to-end pipeline from data collection to MTI generation to MTI message preparation will be evaluated.

PHASE III DUAL USE APPLICATIONS: Phase III efforts would involve enhanced performance capabilities of the prototype autonomous analytics architecture implementation. They will demonstrate autonomous sensing capabilities as part of military exercises and other representative operational environments. Working with transition partners, they will identify and evaluate opportunities for implementation/integration in DoD and/or civilian applications requiring timely data for situational awareness.

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KEYWORDS: autonomous sensing (from space); machine learning analytics; EO/IR imagery; moving target information

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AF221-0026 TITLE: Signal Processing Techniques to Enhance Anti-Jam Performance for Low SWAP-C M-Code-based GPS User Equipment

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Electronics

OBJECTIVE: This topic seeks to identify and research signal processing techniques and/or algorithms improving anti-jam (AJ) performance over current MGUE capability and can be implemented in low size, weight, power, and cost (SWAP-C) military GPS M-code User Equipment utilized in multi-service operational applications.

DESCRIPTION: For nearly three decades, anti-jam (AJ) research and products for GPS User Equipment (UE) have largely been focused on high performance systems like adaptive antenna systems. The capabilities of these primarily hardware-based systems have steadily evolved to extend enhanced AJ performance to military applications with Size, Weight, and Power and Cost (SWaP-C) constraints. In addition, under the MGUE Increment 1 Resiliency and Software Assurance Modification (RSAM) effort, additional receiver-based AJ enhancement techniques were investigated and in part implemented in the MGUE Increment 1 products. Nonetheless, there are still additional challenges in addressing the ever-increasing GPS threats for those military applications and equipment with significant SWaP-C limitations such as handheld receivers, very small, unmanned aerial and ground vehicles, and diver underwater navigation systems where adaptive antenna systems may not be operationally suitable because of array size, high cost, and computational complexity. The objective of this SBIR is to develop and assess single antenna signal processing techniques and algorithms for SWaP constrained M-code capable receiver to enhance the AJ performance by at least 20 dB (30 dB objective) over the current AJ performance specified for the MGUE Increment 1 ground-based receiver in the presence of both narrowband and broadband jammers (e.g., CW, Pulsed CW, Swept CW, Matched Spectral, Gaussian noise). The tradeoffs between jammer suppression, implementation complexity, and SWaP impact should be assessed with respect to representative SWaP constrained military receiver applications and integrations. Evaluate the benefit of utilizing existing built-in sensors like an IMU that are typically integrated within a military diver navigation unit along with an M-code GPS receiver to further enhance jammer suppression. Offerors are encouraged to work with MGUE prime contractors and developers of low SWaP M-code- receiver based systems to help ensure applicability of their efforts and begin work towards technology transition. Offerors' proposals should clearly indicate what Government furnished property or information are required to conduct this effort.

PHASE I: Selected efforts will conduct a comprehensive comparative assessment and trade-offs of pre- and/or post correlation signal processing AJ enhancement algorithms and techniques for implementation with low SWAP-C M-code single antenna receivers and applications such as military underwater navigation systems which utilize various embedded sensors which can aid AJ implementation. Conduct analysis and simulations to demonstrate the level of AJ enhancement over the baseline MGUE Increment 1 AJ performance. Assess implementation complexity of candidate techniques and conduct trade-offs with respect to impact on SWAP-C, AJ performance, and operational suitability. Deliverables will be reporting of trade studies and accompanying analysis.

PHASE II: Companies selected for Phase II will design, implement, integrate, and test the most promising and effective low SWAP-C AJ signal processing/algorithmic techniques with a representative M-code based receiver prototype to demonstrate AJ implementation and performance applicable to evolving low SWaP M-code based receivers. Efforts will demonstrate measurable AJ performance with the prototype utilizing representative sensor inputs like those provided by an M-code receiver-based military underwater navigation system. Deliverables will include any software or hardware demonstrations used for analysis and reporting.

PHASE III DUAL USE APPLICATIONS: In cooperative efforts with one or more M-code-based receiver manufacturers and military underwater navigation system developers, integrate the proposed signal processing/algorithmic techniques with their respective products. Demonstrate the AJ performance, SWaP compatibility, and operational effectiveness of the algorithmic/signal processing enhancements in one or more upgraded products utilizing laboratory and field tests in representative operational and EW environments. Evaluate transition opportunities for utilization in approved Government civilian applications.

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KEYWORDS: GPS M-code; anti-jam; signal processing

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AF221-0027 TITLE: Autonomous Target Track Management by Proliferated Space Constellations

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: The objective of this topic is to conceptualize, design, and develop a prototype of an on-orbit AI expert system for autonomous target track management by a proliferated constellation of LEO satellites. Additionally, this topic seeks to conceptualize, design, and develop a prototype of an on-orbit AI expert system for autonomous target track management in conjunction with autonomous tip & cue by a proliferated constellation of LEO satellites. This research effort specifically seeks to develop an expert system with an architecture consisting of an iterative knowledge base and an inference engine enabling autonomous track management of in-flight tactical aircraft and other airborne tactical targets. Since each satellite's expert system operates in a sensor/satellite network, technology development is also needed focusing on the potential efficiency to be gained by utilizing AI technology to enable on-orbit decisions that a) incorporate messaging traffic from other satellites in the constellation and b) allow for continuous track coordination and management across the entire constellation. AI concepts and methods are therefore also sought to facilitate and prioritize decision-making about what message content needs to be transmitted to which satellite(s) and when. Tipping & cueing all satellites in the constellation would be very inefficient and delay alerts to those satellites most likely to next view the target; however, some satellites might need a message which summarizes AMTI information whereas other satellites might need additional track information in order to fill gaps in partial or incomplete tracks.

DESCRIPTION: The DoD's all-domain intelligence, surveillance, and reconnaissance (ISR) enterprise is pursuing the development and integration of transformative capabilities needed to detect, track, and target current and future threats posed by potential adversaries. Autonomous sensing is one such innovative capability emerging as an integral technology enabler of space based tactical ISR in order to meet increasingly demanding target tracking challenges. This paradigm shift from traditional space-based surveillance systems and CONOPS to increasingly more autonomous mission operations depend on distributed and disaggregated space architectures controlled and supervised by on-orbit autonomous agents for data processing, information analysis, and course-of-action (COA) decision-making. Among these new space architectures being considered are proliferated LEO (pLEO) satellite constellations which will require many more satellites for coverage compared to other traditional orbit regimes and therefore will need to conduct mission operations in an entirely new way to minimize the large numbers of satellite operators otherwise needed to maintain the entire constellation, especially given tactical timelines requiring rapid on-orbit decision-making. One approach, therefore, to pLEO operations is for each satellite to have an onboard expert system, namely, an application using artificial intelligence (AI) to build a knowledge base which is then used to solve complex problems and make decisions without a human expert in the loop. In particular, on-orbit knowledge-based systems acting/reacting to events is central to decision-making for pLEO satellite constellations expected to coordinate and manage tipping & cueing operations among networked sensors and satellites for detecting and tracking targets. When and how an on-board expert, decision-making, system acts in response to a new observable or detected event is thus critical to the performance of autonomous tip & cue for target track management by a hybrid, multi-layered space architecture. In order to address this challenge, this research topic seeks innovative AI solutions to the design and development of an on-orbit expert system applying reasoning logic and processes to infer new information from a knowledge base of air moving target indication

(AMTI) data. The overarching goal and desired end state of this topic is an on-orbit expert system for autonomous target tracking by networked sensors/satellites in proliferated LEO constellations.

One of the challenges for on-orbit autonomous tip & cue is how to interpret data products and make dynamic decisions about courses of action while at the same time processing sensor data using trained machine learning algorithms. The technology to be developed should therefore focus on the need for innovative AI approaches and methods that enable an on-orbit autonomous expert system to make tip & cue decisions based on air moving target indication (AMTI) information that is a) characterized by statistical and probabilistic metrics for true positive/true negative classification outcomes as well as for false positive/false negative classification outcomes, b) then turned into partial track information, and c) then turned into complete tracks after processing track messages that received from other satellites that contain information on target position and velocity uncertainty. Integral to this technology development effort is the control and management of autonomous tips & cues by an expert system that acts on true target detections and disregards false alarms, but also takes into account predicted target trajectories based on a pattern of observed AMTI data. This topic thus seeks innovative AI methods which incorporate reasoning processes with feedback mechanisms that can generalize existing knowledge of the performance of the space architecture as well as incorporate new knowledge to facilitate the on-orbit decision-making process.

This topic includes research that utilizes airborne autonomous expert systems as a starting point for developing an expert system for autonomous target track management by pLEO satellite constellations. An important aim of this topic is to design and integrate technologies that make possible the decentralized operation of networked on-orbit expert systems since the convergence of sensor and communication capabilities within a proliferated constellation is a unique advantage of autonomous target tracking by hybrid space architectures being considered for tactical surveillance.

PHASE I: Phase I efforts will conduct a review and assessment of candidate AI approaches and methods for developing an expert system for autonomous target track management by proliferated space constellations. Selected companies will investigate reasoning rules/processes and develop a conceptual framework for a knowledge-based expert system with inference engine for making tip & cue decisions using knowledge of air moving target indication (AMTI) data. They will expand the conceptual framework to a preliminary design of an expert system for coordinating and managing target tracking across all satellites of a proliferated LEO constellation. Further, they will evaluate the mission challenges and impacts of implementing autonomous target track management on low-medium SWAP satellites.

PHASE II: Selected Phase II companies will finalize design of AI knowledge-based architecture and develop a prototype expert system for autonomous target track management by proliferated space constellations. Efforts will design and develop a simulated test environment for validating and demonstrating the autonomous functionality and operations of the prototype expert system. Assess performance of the prototype expert system against relevant benchmarks and metrics. They will investigate the feasibility of using digital engineering approaches to create a digital twin of a physical onboard expert system device.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will enhance performance capabilities of the prototype expert system and use the identified improvements to produce an expert system with autonomous decision-making capabilities for on-orbit tip & cue and target track management. They will demonstrate autonomous functionality and operations of the expert system as part of tabletop exercises, simulated wargames and/or other representative operational-like environments. To the extent possible, they will develop a digital twin of the physical onboard expert system device. Working with commercial and government transition partners, companies will identify and evaluate opportunities for implementing/integrating the physical or digital expert system in DoD and/or civilian applications requiring autonomous, real-time decision-making for situations involving large, complex, and dynamic data sets for which actionable information can result in multiple courses of action with varying consequences and impacts. Commercial applications could include, for example, autonomous driving vehicles and robotic devices for household or business use requiring continuous monitoring of coordinated/collective tasks. Financial and manufacturing decisions might also benefit from an autonomous expert system. Additional DoD applications might include visual scene recognition in multi-domain common operating picture (COP) systems as well as mission operations for UAV/UAS swarms in environments with limited communications.

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KEYWORDS: AI expert systems; autonomous satellites; autonomous reasoning systems; machine learning methods for autonomy; networked autonomous systems; target tracking management

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AF221-0028 TITLE: Novel Analytics for Characterizing Influence in Visual and Audio Social Cyber Data

TECH FOCUS AREAS: Cybersecurity

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: This topic's objective is to develop, demonstrate and transition analytics to detect, classify and forecast the impact of information maneuvers (based on BEND information maneuvers framework) based on visual content (video, memes and pictures) and audio chat in order to support meaning making and decision-making regarding influence, course of action assessment and forecasting of behaviors, events. No BEND analytics currently exist for visual content. In fact, limited analytics for visual content exist at all -- they largely address activity detection, actor detection (akin to "entity detection" or "event detection") or characterization of affect. Likewise, there are not BEND (influence characterization) analytics for audio chat, as this is an emerging online discourse space. Current audio-based analytics focused on content, role taking within conversations ("politeness", etc.) could be leveraged to develop new analytics to characterize influence in this domain.

DESCRIPTION: Operating in the information environment today is highly challenging for military warfighters. Due to the difficulty in assessing influence in social media, a Social Digital Media playbook was developed to help characterize actions, events, and communications (Beskow and Carley, 2019). Specifically, the BEND framework accounts for how social media algorithms interact with different user activities. There are sixteen simple information maneuvers with half being community maneuvers and half being content maneuvers. Research is needed to extract the maneuvers from visual content (e.g., videos, memes) and also to better visualize the maneuvers. Additionally, research is needed on social media platforms beyond Twitter and with emerging platforms and capabilities such as voice chat (e.g., clubhouse). New analytics can assist planners, information operators, intelligence analysts with adaptive planning, triggering and cueing of sensors, strategic communication, etc. Further, by understanding the online behaviors and mechanisms of influence, it can help forecast behaviors offline (e.g., civil unrest leading to protests) which could lead to better military intervention strategies. Ideally, the approaches will include multiple parameter spaces to control for various knowledge topics, different events, varying network sizes, and different actors (including bots). Capabilities including non-English speaking contexts would particularly align with this topic. Approaches solely focused on disinformation (e.g., fake news, deepfakes) do not align with this topic. No government furnished materials, equipment, data, or facilities will be provided.

PHASE I: Develop software (analytic algorithms, models, and visualization) for characterizing the 16 BEND information maneuvers that are visual (e.g., images, memes, videos) and / or voice (e.g., voice chat). Proof of concept demonstration of the software for detection and classification of 4 BEND maneuvers from each type (content -- positive, negative, network -- positive, negative) across multiple types of visual content (videos, memes, pictures) and/or audio chat (e.g., Clubhouse). Deliverables are detection, classification, visualization software as well as full documentation of algorithms and characterization of algorithms (Receiver Operating Characteristic curves) for detection and classification software and narrative addressing proposed approach for expanding to all 16 BEND maneuvers in final report.

PHASE II: Companies selected for Phase II will apply the knowledge gained in Phase I to mature and integrate analytics and to further develop the interface, capabilities and training components needed to make the technologies transition to military customers, marketing, etc. Expand and develop the model to cope with real-time information flows and evolving information tactics. Demonstration of detection, classification of all (16) BEND maneuvers, including detection, classification of associated maneuvers in campaign (e.g., BOOST and BUILD maneuvers) in visual content (videos, memes, pictures) and/or audio chat. Anticipate/forecast impact on target audiences. Deliverables are software for detection, classification, visualization of both individual BEND maneuvers as well as associated maneuvers as well as a final report with full documentation of algorithms and characterization of algorithms (Receiver Operating Characteristic curves) for detection and classification software and narrative addressing proposed approach for visualization of influence campaigns, operationalization/transition to customers, including drill-down, supporting information to support meaning making by operators and anticipated/forecasted impact on target audiences. Additional deliverable is a software test dataset to be used to demonstrate the software/visualization to customers.

PHASE III DUAL USE APPLICATIONS: Phase IIIs will apply the knowledge gained in Phase II to further develop the interface, capabilities and training components needed to make the technologies transition to military customers, marketing, etc. They will expand and develop the model to cope with real-time information flows and evolving information tactics. Efforts will demonstrate ability to detect, classification of BEND maneuvers, including a campaign (associated BEND maneuvers) in visual content (videos, memes, pictures) and audio chat. Further, they will demonstrate capability for users to visualize maneuvers, drill down to data, and forecast impacts on target audiences, including the impacts of counter maneuvers.

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KEYWORDS: social-cyber data; social media analytics; network analytics; social media visualization; audio chat; voice chat; forecasting; classification; influence; actors; communities; networks; maneuvers; information maneuvers; influence; information operations; deep fakes; bots; information maneuver

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AF221-0029 TITLE: Big Data Analytics for Managing and Parsing Computational and Experimental Data

TECH FOCUS AREAS: Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Sensors; Air Platform

OBJECTIVE: This topic seeks to develop a software suite to analyze large time-dependent datasets by extracting insights with user-friendly statistical, decomposition, and system identification methods.

DESCRIPTION: Simulation-based evolution of military aircraft designs is increasingly dependent on computational techniques. High-fidelity unsteady databases of aircraft and sub-systems are becoming increasingly common. Suitable post-processing tools to analyze the large datasets produced have the potential to greatly speed up the evolution of optimal designs to fulfill different objectives. Experimental data acquisition has also reached maturity, and high-resolution volume data, comprising large data storage sizes, can increasingly be obtained very quickly. The ability of computational and experimental methods to generate large datasets has far exceeded analysis capabilities. Thus, only a small amount of the data is actually employed to generate insights, most frequently to determine integrated performance measures. The rich information encapsulated in the database is often neglected for lack of human resources required to perform tedious and systematic data exploration. Such information, including various phenomena of practical interest, such as flow separation, vortical structure formation, coherent structure dynamics and intermittent features among others, as well as methods to identify sensitivities of the flow-field, could not only accelerate development, but may provide significant guidance in the implementation of optimal control techniques or inform reduced-order-model development. This bottleneck must be overcome to aid design engineers and program managers in their quest for intelligent assessments of promising designs, ways to optimize this development, and to guide future simulations/experiments. A need exists to develop a suite of analytical tools capable of extracting key features from large databases, and their sensitivities, so as to provide meaningful and relevant information with minimal human involvement.

PHASE I: Phase I efforts will define and develop a concept for a software solution with ability to analyze large time-dependent data sets from computations and experiments with minimal human involvement. Efforts will define a methodology or approach for standardizing the data from disparate sources. The concept should include the initial design specifications and capabilities description to build a prototype solution in Phase II. Three Phase I solutions will be sought.

PHASE II: Based on the Phase I concept, selected efforts will design, develop, and deliver a prototype solution with the ability to analyze large unsteady data sets. The prototype must be capable of successfully demonstrating an ability to identify useful information to be used for decision making by designers and engineers. Efforts will demonstrate the tool capability with the relevant datasets. A Phase III qualification and transition plan is expected to be delivered at the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Based upon the success of Phase II, the developed product would be transitioned to DoD and integrated into its required software systems. Many commercial entities and non-DoD organizations may have interest in this technology.

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KEYWORDS: modal analysis; proper orthogonal decomposition; dynamic mode decomposition; resolvent analysis; stability analysis; feature extraction; reduced-order modeling; fluid dynamics; machine-learning

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AF221-0030 TITLE: Event-Based Infrared Read-Out Integrated Circuit for Neuromorphic Processing

TECH FOCUS AREAS: Microelectronics

TECHNOLOGY AREAS: Sensors

OBJECTIVE: This topic seeks to model, design, and produce an asynchronous, event-based infrared read out integrated circuit (ROIC) with low power, medium array format, and digital outputs compatible with neuromorphic algorithms.

DESCRIPTION: Low power consumption is a persistent goal of military imaging systems. The power consumption is derived from three principal components: operate the imager, process the data, and transmit the image. Infrared imagers in particular must operate at low power levels (less than 500 mW), as power dissipation through the ROIC is more than doubled by the cryogenic cooling requirements, i.e., 1 W of dissipated power in the ROIC will require far more than 1 W of additional cooling capacity by the cryogenic cooler. A strong desire exists to reduce the power consumption in the ROIC and the data processing. Several groups have recently demonstrated low power, event-based sensors in the visible spectrum. These sensors are effectively asynchronous change detection circuits that only send data when the scene changes and produce a basic mapping of where light levels increased and where they decreased. Since a static scene produces no change in the circuit, the data rate and power consumption can be reduced dramatically. Furthermore, neuromorphic processing algorithms have been able to utilize this data directly to perform complicated tasks such as optical flow tracking, automatic target recognition, and stereo imaging. Recent designs have also featured grayscale imaging to enhance the user experience. The combination of both low power operation and processing has the potential to change the imaging paradigm for many systems but has only been demonstrated in the visible spectrum thus far. The goal of this program is (a) to model an event based infrared ROIC in Phase I, (b) to design, develop, and produce the ROIC in Phase II, and (c) to hybridize and demonstrate a full array with neuromorphic processing capabilities in Phase III. The basic requirements for meeting these goals are array formats of 320 x 256 or larger; pixel pitches of 40 microns or smaller; reset times of 10 microseconds or faster; an asynchronous, digital output capable of more than 1E9 events per second; grayscale imaging of 8 bits or greater; and static scene power consumption of 10 mW or less at 120 K. Preference will be given to systems run from commercial infrared camera test dewars with minimal modifications, as well as designs operating using detector material for SWIR (0.9-1.7 μm), MWIR (3-5 μm), or LWIR (8-12 μm). No government-furnished equipment, data, and/or facilities will be provided.

PHASE I: Selected Phase I efforts will develop a model for an event based infrared ROIC and imager using provided detector models. The model will be delivered in the form of code (e.g., Matlab, Python) for verification and future validation.

PHASE II: Companies selected for Phase II will design and produce an asynchronous ROIC based on the models at the desired array size and pixel pitch. Efforts will demonstrate low power operation under static scenes, as well as high speed operation. Both hybridized focalplane arrays and unhybridized ROICs will be delivered for testing, with supporting hardware interface control documentation and control software.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will demonstrate a fully packaged camera with a neuromorphic processing chip. Spiking neural network device technology is preferable. Efforts will leverage emerging event-based sensing algorithms to demonstrate.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: Neuromorphic imaging; event-based imager; read out integrated circuit; ROIC; infrared detector; infrared camera; asynchronous time-based image sensor

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AF221-0031 TITLE: Publicly Available Information (PAI) Collection Management

TECH FOCUS AREAS: Cybersecurity; Network Command, Control and Communications; Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: This topic seeks to develop an algorithmic approach and software framework for automated collection management across PAI sources, with the ability to generate RFIs for ISR sources, enabling improved relevance and accuracy in event discovery and threat forecasting

DESCRIPTION: Publicly Available Information (PAI) data sources are growing in volume and velocity and can provide critical and timely information about important events, such as changes in an adversary's threat posture. However, these datasets include significant irrelevant, incorrect, or incomplete information. Prioritization, verification, and supplementation are therefore essential to identify and analyze critical events. However, given the volume of data, much of this work must be automated. Previous research in "hard-soft fusion", combining PAI with traditional Intelligence, Surveillance, and Reconnaissance (ISR) sources, has shown promising strides toward identifying and verifying relevant events based on evidence spanning these disparate sources [1] [2]. Recent research in the intelligence community has also shown the potential to exploit disparate data sources to predict future threats in specific categories [3] [4]. However, a key enabler for such event discovery and threat forecasting capabilities is the ability to manage data collection to ensure detected events and threats are relevant to Air Force analysts and warfighters. While significant work in collection planning has been performed in single domains or for single INT sources such as satellite imagery [5], managing collection jointly across disparate PAI sources with coordinated cueing of more constrained ISR sources remains a challenging, unsolved problem.

The objective of this topic is to design and develop an algorithmic approach and software framework for automated collection management spanning disparate PAI sources and modalities, with support for cueing of traditional ISR or other non-PAI sources via Requests for Information (RFI) messaging. The framework should address the following specific challenges:

1. Prioritizing and optimizing PAI collection based on analysts' interests, to improve relevance of discovered events. A machine representation of analyst interests is an important aspect of this problem.

2. Prioritizing and cueing follow-up collection to gather additional information on discovered events, to improve characterization and understanding of the discovered events. This may include evidence from alternative PAI sources or modalities, as well as traditional ISR or non-PAI sources and modalities. As an example, a PAI MOVINT indication of troops massing at a border can be corroborated by satellite IMINT, providing both higher confidence and more actionable information about the event.

3. An additional challenge is that of prioritizing and organizing what is reported to analysts based on what is found by the automated collection and downstream event discovery and threat forecasting systems, to improve relevance of reported events. Addressing this challenge can leverage existing algorithms in these areas, simplified software approximating such algorithms, human judgment, or a combination of these methods.

For Phase I and II, developed software and data shall be unclassified. Generation of unclassified RFIs is sufficient for ISR sources and domains where the collected data itself is typically classified.
The resulting algorithmic framework will help “get the right decision quality data to the right decision-maker at the speed of relevance” [6]. It will also provide a useful foundation for transition into emerging hard-soft fusion analytics tool chains for military JADC2 decision-makers, with strong potential for applications in the commercial sector.

PHASE I: Phase I efforts will design algorithms to prioritize collection of PAI and cueing of supporting ISR data to support discovery of relevant events and threats spanning disparate sources and modalities. The algorithms should ingest PAI and incorporate at least two modalities in Phase I, and demonstrate generation of RFIs for at least one ISR or non-PAI source. The output should be ranked lists of events for Challenges 1 and 2 and formatted RFIs for additional data for Challenge 3. Programs should also demonstrate proof-of-concept for these algorithms on domain-relevant data sets and evaluate relevance of results.

PHASE II: Phase II efforts will develop a prototype system implementing the Phase I design and continue to thoroughly test and validate the Phase I algorithms by leveraging an expanded range of datasets. Phase II efforts will deliver software and support on-site integration and testing in customer environment.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will produce empirically validated methods for automated multi-modal collection management improving relevance, actionability, and collection efficiency of military intelligence. Commercial applications for these solutions would include public health and safety, law enforcement, and news reporting.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: ISR; Cyber; Algorithmic; Discovery; Forecasting; Collection Planning; PAI Sources

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AF221-0032 TITLE: Low-Cost Scalable Ultrawideband Receiver Personality for Attritable Platforms

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Sensors; Electronics; Air Platform

OBJECTIVE: This topic seeks to develop a multi-channel 2-18 GHz receive-only RF personality subsystem to interface with conformal antenna arrays and the Zynq UltraScale+ RFSoC analog-to-digital system-on-chip devices. The developed receiver personality will leverage a commercial off the shelf open architecture approach to reduce cost and be form factored to integrate inside the size, weight, and power (SWaP) limitations of platforms such as the AgilePod(tm) and Valkyrie XQ58A nose cones.

DESCRIPTION: To operate effectively in highly contested environments, there is a critical need for distributed multi-function RF sensing capabilities on attritable platforms supporting integration into a dynamic battlefield environment within the sensing grid construct of the Air Battle Management System (ABMS). The Department of Defense (DoD) is developing the next generation of conformal phased array technologies with highly flexible, scalable, and reconfigurable RF digital backends, also known as digital receiver/exciter (DREX). These DREX modules operate over wide frequency bands and support many channels in a small SWaP form factor. Current multi-channel phased array receiver personalities, however, are still too expensive and have limited modularity for scaling capabilities in attritable-class platforms. In order to further reduce system life cycle costs and increase the ease of upgradability, next generation phase array technologies need to support common interfaces, such as Sensor Open Systems Architecture (SOSA), and modular subsystem integration approaches.

The goal of this topic area is to develop a modular and scalable receive-only RF personality directly connected with structurally integrated conformal antenna arrays and the Zynq UltraScale+ RFSoC for future SIGINT/ELINT, radar warning receiver (RWR), bistatic synthetic aperture radar, and bistatic ground moving target indicator radar capability demonstrations. Recent significant advances in commercially available RF electronics will enable performance improvements to a receiver's instantaneous bandwidth and sensitivity while lowering system costs.

The Air Force seeks a scalable receive-only 32-channel and 128-channel RF personality operating from 2-18 GHz (threshold requirement of 6-18 GHz) with a tunable bandwidth of 50-4000 MHz, spur free dynamic range of at least 90 dB, and Noise Figure better than 8 dB. The ADC sampling rate and effective number of bits (ENOB) will be defined by the Zynq UltraScale+ RFSoC, with further DREX subsystem and conformal antenna array interface details provided by the Air Force at the beginning of Phase 1. No other government materials, equipment, data, or facilities are required for successful program completion. The developed RF personality should adhere to the 3U OpenVPX form factor, which defines maximum size, weight, power, and cooling per slot (see ANSI/VITA 65-2017). Likewise, the design must include at least 16 channels per VPX card to support standard phase array system architectures. The developed personality architecture needs to be readily scalable beyond 128-channels in order to support future sensing needs. Additionally, the RF personality must include functionality to enable a hybrid analog/digital subarray beamforming architecture. Each RF path must incorporate phase and amplitude control to support this RF system architecture.

PHASE I: Phase I efforts will design a high-fidelity RF systems model of the receive-only RF personality to meet the performance objectives outlined in the description. Phase I companies will perform modeling, simulation and analysis trade-studies to identify the optimal approach and demonstrate concept feasibility of expected performance, size, weight, power consumption, and cooling considerations. The high-fidelity model will be delivered to the Air Force, as well as a Phase II work breakdown structure and dual-use strategy.

PHASE II: Phase II efforts will develop and deliver a prototype 32-channel and 128-channel receive-only RF personality meeting the topic performance requirements (TRL 4 demonstration criteria). Experimental measurements will be performed to verify performance. Additionally, an interface control document detailing aspects such as mechanical, electrical, and control interfaces will be delivered to the Air Force.

PHASE III DUAL USE APPLICATIONS: In Phase III, the company will assist the Air Force to adapt and transition the technology to the AgilePodtm program through Advanced Technologies Branch of the ISR Sensors Division (AFLCMC/WINA) and Kratos XQ-58 Valkyrie low-cost attritable strike demonstrator (LCASD) program. This technology has the potential to improve many other military systems across multiple agencies and other on-going small UAS programs. The company will actively engage with the Air Force to improve the TRL and adapt the technology to enhance future mission areas. Additionally, the developed technology may be readily adopted and commercialized in the rapidly growing satellite communications market for high data rate MIMO ground stations as well as the wireless mobile backhaul markets.

NOTES: 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 proposed 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 questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

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KEYWORDS: Ultrawideband; High Dynamic Range; Digital Receiver; RF Personality

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AF221-0033 TITLE: Evolvable Software Workbench for Avionics Cyber Security

TECH FOCUS AREAS: Cybersecurity; Autonomy; Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Sensors

OBJECTIVE: This topic seeks to develop and explore a software evolution workbench to remove malware from software/firmware, improve detection algorithms and malware understanding, and develop the means to provide software diversity to mitigate cyber-attacks.

DESCRIPTION: The ability to prevent, detect, and respond to avionics supply chain attacks and measure the effectiveness of existing cyber defense solutions remains an unsolved problem. Recent Solarwinds supply chain attacks compromising numerous U.S. government agencies highlight the impact of such a threat and the pressing, paramount need to develop solutions removing or detecting and responding to malware implanted in legitimate software and firmware. Several research efforts have proposed a variety of evolutionary approaches to address this problem.

For example, [1] argues introducing artificial software diversity into a potentially targeted program significantly decreases the probability of compromise since the evolved implementation is unknown to the attacker. In [2], a thorough survey of demonstrations where several attacks are mitigated using an automated software diversity approach is presented. The literature also includes optimizing the evolutionary process by identifying the target of diversification (e.g., instructions, basic blocks, loops) and the stage in the software life cycle for which diversification occurs (e.g., installation, loading, execution, updating) [2]. Many of the methods in the literature make use of Genetic Programming (GP) to carry out the evolutionary process [3,4]. In addition, software evolution has been used to automatically generate bug fixes [5]. Evolutionary-based diversification has therefore proven to be a useful tool in mitigating various attacks by attempting to create immune variations of programs and/or patching vulnerabilities. However, current evolutionary approaches are very inefficient as they produce non-functional mutations, not only due to the randomness in the approach but also brittleness of the computer language being evolved. In fact, 99.7% of all software mutations are found to be non-beneficial, making evolvability in existing languages computationally burdensome and very limited in producing acceptable results [6].

The goal of this topic is to develop and explore an evolvable software language and methodologies to overcome the above limitations. Specifically, this topic will focus in developing a methodology that yields fully executable programs and the means to yield the desired program functionality. The workbench will be used to 1) generate novel malware samples to evaluate and measure the effectiveness of avionics malware detection solutions against quantifiable metrics, 2) enhance existing malware detection tools, and 3) provide the means to eliminate supply chain malware by deliberately evolving the targeted legitimate software so as to “evolve out” any Trojan that may reside within that software. Additional requirements for malware generation include the ability of the evolved software to pass regression tests of the original program, avoid detection, and have the desired mission impact based on a user-configurable fitness function.

PHASE I: Phase I efforts will develop a software evolution workbench preliminary prototype demonstrating ability to evolve programs satisfying syntactic and semantic constraints. Use of government materials, equipment and facilities are not required for this research effort. Deliverables for this phase include developed software i.e., evolvable software workbench, and manual/documentation.

PHASE II: Extend the workbench developed in Phase I to demonstrate that it can efficiently and effectively both generate novel malware that meets the above requirements and remove Trojans from legitimate software applications. Deliverables for the second phase include software of the comprehensive workbench, the generated malware samples, the successful demonstration of evolving out a Trojan from a legitimate application and corresponding documentation.

PHASE III DUAL USE APPLICATIONS: The final product will include a two-way automated translator that can ingest programs into the evolvable workbench and the evolved program can be translated back to the original instruction set architecture (e.g., 32-bit generation Intel microprocessor architecture [x86], Advanced Reduced Instruction Set Computing Machines [ARM]). Military applications include both manned and unmanned aerial vehicles, and advanced sensor systems. Commercial applications include embedded systems such as autonomous driving vehicles and Supervisory Control and Data Acquisition (SCADA) systems.

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KEYWORDS: Malware Detection and Response; Evolutionary Computing; Genetic Algorithms; Evolvable Software; Avionics Cyber Security

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