DEPARTMENT OF THE AIR FORCE
22.4 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
Air Force Release 2 (AR2)

Amendment 2

18 August 2022

This Amendment accomplishes the following revisions:

1) Topic AF224-0002. References #5 and #7 have been removed.

All other provisions remain unchanged as a result of this Amendment.

DEPARTMENT OF THE AIR FORCE
22.4 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
Air Force Release 2 (AR2)

Amendment 1

11 August 2022

This amendment accomplishes the following revisions:

1) Topic AF224-007 “Tactical Laser Communications” is removed from this solicitation.

All other provisions remain unchanged as a result of this Amendment.

DEPARTMENT OF THE AIR FORCE
22.4 Small Business Innovation Research (SBIR) Phase I
Proposal Submission Instructions
Air Force Release 2 (AR2)

The Air Force intends these Phase I proposal submission instructions to clarify the Department of Defense (DoD) Broad Agency Announcement (BAA) as it applies to the topics solicited herein. **Offerers must ensure proposals meet all requirements of the 22.4 SBIR BAA posted on the Defense SBIR/STTR Innovation Portal (DSIP) at the proposal submission deadline date/time outlined in this document.**

The following dates are applicable to this solicitation:

Topic Number	Topic Title	Release Dates
SF224-0001	Electro-Optical Pre-Custody Threat Warning	**Pre-Release:** 11 August 2022 **Open:** 1 September 2022 **Close:** 29 September 2022 at 12:00pm ET **Question & Answer Period Close:** 15 September 2022 at 12:00pm ET
AF224-0002	Novel Architectures for Reduced CSWAP Multidimensional Imaging LiDAR	
AF224-0003	20 MW Microwave Source Set with C- to Low K-Band Coverage	
AF224-0004	X-Band RF Linear Accelerator	
AF224-0005	High Brightness Mid-IR Laser Illuminator	
AF224-0006	High Power Microwave Applications for Water Conservation	
AF224-0007	Topic Removed	
AF224-0008	Digital Multisensory Augmented Reality for Special Warfare (DMARS)	
SF224-0009	Novel Metrology Solutions for Space Based Antennas	
SF224-0010	On-Orbit Assembly and Manufacturing for Space-Based Antennas	
AF224-0011	Software-Defined Networking (SDN) enabled Satellite Bandwidth on Demand	
SF224-0012	Customer Functions Virtualization over Satellite Terminals	
AF224-0013	Advanced Ceramic Electrochemical Cell for Oxygen Production	
SF224-0014	Energy Harvesting	
AF224-0015	Forward Error Correction Codes for Ultra-Reliable Low-Latency Global Navigation Satellite Systems (GNSS) Signals	

Chart 1: Air Force 22.4 SBIR Phase I Topic Information at a Glance

Topic Number	Topic Title	Maximum Price	Maximum Period of Performance (PoP)	Technical Volume Page Limit
SF224-0001	Electro-Optical Pre-Custody Threat Warning	$150,000	9 Months	20 Pages
AF224-0002	Novel Architectures for Reduced CSWAP Multidimensional Imaging LiDAR	$150,000	9 Months	20 Pages
AF224-0003	20 MW Microwave Source Set with C- to Low K-Band Coverage	$150,000	9 Months	20 Pages
AF224-0004	X-Band RF Linear Accelerator	$150,000	9 Months	20 Pages
AF224-0005	High Brightness Mid-IR Laser Illuminator	$150,000	9 Months	20 Pages
AF224-0006	High Power Microwave Applications for Water Conservation	$150,000	9 Months	20 Pages
AF224-0007	Topic Removed			
AF224-0008	Digital Multisensory Augmented Reality for Special Warfare (DMARS)	$150,000	9 Months	20 Pages
SF224-0009	Novel Metrology Solutions for Space Based Antennas	$150,000	9 Months	20 Pages
SF224-0010	On-Orbit Assembly and Manufacturing for Space-Based Antennas	$150,000	9 Months	20 Pages
AF224-0011	Software-Defined Networking (SDN) enabled Satellite Bandwidth on Demand	$150,000	9 Months	20 Pages
SF224-0012	Customer Functions Virtualization over Satellite Terminals	$150,000	9 Months	20 Pages
AF224-0013	Advanced Ceramic Electrochemical Cell for Oxygen Production	$150,000	9 Months	20 Pages
SF224-	Energy Harvesting	$150,000	9 Months	20 Pages

0014				
AF224-0015	Forward Error Correction Codes for Ultra-Reliable Low-Latency Global Navigation Satellite Systems (GNSS) Signals	$150,000	9 Months	20 Pages

Complete proposals **must** be prepared and submitted via https://www.dodsbirsttr.mil/submissions/ (DSIP) on or before the date published in the DoD 22.4 SBIR BAA. Offerers are responsible for ensuring proposals comply with the requirements in the most current version of this instruction at the proposal submission deadline date/time.

The AF recommends early submission, as computer traffic gets heavy near the proposal submission date/time and could slow down the system. **Do not wait until the last minute.** The AF is not responsible for incomplete proposal submission due to system lag or inaccessibility. Please ensure contact information, i.e., names/phone numbers/email addresses, in the proposal is current and accurate. The AF is not responsible for ensuring notifications are received by firms for which this information changes after proposal submission without proper notification. Changes of this nature shall be sent to the Air Force SBIR/STTR One Help Desk.

Please ensure all e-mail addresses listed in the proposal are current and accurate. The DAF 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, “22.4 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 22.4 SBIR BAA.
- Air Force SBIR/STTR Contracting Officer (CO):
    - Mr. Daniel Brewer, Daniel.Brewer.13@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.

PHASE I PROPOSAL SUBMISSION: The DoD 22.4 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 DAF, 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/slide 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/slides 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. **Note:** Do not upload information such as Permanent Resident Cards (Green Cards), birth certificates, Social Security Numbers, or other PII to the DSIP system.

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

<u>Cost Volume</u>: 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, Special 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 special test equipment purchases must, in the CO’s opinion, be advantageous to the Government and relate directly to the effort. These toolings or equipment should not be of a type that an offeror would otherwise possess in the normal course of business. These 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. Material costs may include the costs of such items as raw materials, parts, subassemblies, components, and manufacturing supplies.

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 v. purchase justification.

d. **Direct Labor**: Identify key personnel by name, if possible, or bylabor category, if not. Direct labor hours, labor overhead and/or fringe benefits, and actual hourly rates for each individual are also necessary for the CO to determine whether these hours, fringe rates, and hourly rates are fair and reasonable.

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 (<u>do not include profit in the calculation</u>), 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 exchanges. 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 doing so 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 shall not include TABA.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Firms shall register in the System for Award Management (SAM) at https://www.sam.gov/, to be eligible for proposal acceptance. Follow instructions located in SAM to obtain a Commercial and Government Entity (CAGE) code and Unique Entity Identifier (UEI) 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. The AF will not accept alternative means of submission outside of DSIP.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in the 22.4 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 22.4 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.

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 Officer Daniel Brewer, Daniel.Brewer.13@us.af.mil.

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 22.4 SBIR BAA Phase II review criteria.

Phase II is the demonstration of the technology found feasible in Phase I. Only Phase I awardees are eligible to submit a Phase II proposal. All Phase I awardees will be sent a notification with the Phase II proposal submittal date and detailed Phase II proposal preparation instructions. If the physical or email addresses or firm points of contact have changed since submission of the Phase I proposal, correct information shall be sent to the AF SBIR/STTR One Help Desk as instructed on A-1. Phase II dollar values, performance periods, and proposal content will be specified in the Phase II request for proposal.

NOTE: The 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, including award of Cost-Reimbursement types of contracts. 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 22.4 SBIR Topic Index
Release 2

SF224-0001	Electro-Optical Pre-Custody Threat Warning
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SF224-0001 TITLE: Electro-Optical Pre-Custody Threat Warning

TECH FOCUS AREAS: Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: Develop a process to produce actionable information for the warfighter from non-resolved space object imagery prior to observation-catalog association.

DESCRIPTION: Space objects are becoming smaller and more prolific while the domain is increasingly congested, contested, and competitive. Government and commercial ground-based telescopes were proliferated to maximize the number of observations and awareness of the space domain. As a result of the significant increase in data volume, space domain awareness architectures have been driven to automate the processing and exploitation of optical imagery. Most images are never viewed or inspected by a human operator. Potential threat events, such as Closely Spaced Objects (CSOs) and breakup events are easily identified visually in calibrated imagery; however, it is not practical to send frames or thumbnails to a centralized location for visual inspection. This process stresses the available communications bandwidth and is manually intensive. As a result, the warfighter must wait for minutes to hours while the extracted detections are filtered, frame-to-frame associated, correlated to known objects, classified as Uncorrelated Targets (UCTs), and deemed a potential threat by additional processing. This information is commonly insufficient to determine threat levels and the operator must request imagery transfers to perform visual inspection which can take days to complete. Consequently, the operator is unable to effectively perform Courses of Action (COAs) selection and execution. The USSF needs an automated process that runs at the sensor locations to recognize potential threat events in imagery to alert operators on relevant timelines.

PHASE I: Identify types of events that can be visually categorized in non-resolved imagery. Generate potential strategies for automating real-time processes to identify the types of events prior to downstream processing. Identify the key technical challenges and Technical Readiness Level of the proposed approach. Generate a technology maturation plan to mature the proposed approaches.

PHASE II: Generate real or simulated imagery for testing. Develop prototype software to generate alerts that enable operator COA selection and execution in less than 10 seconds of imagery collection without access to a known object state estimate catalog. Compare performance to traditional processing approaches. Demonstrate the ability to significantly reduce the number of false positives, false negatives, and alert delivery latency.

PHASE III DUAL USE APPLICATIONS: Mature prototype software into a commercial product for commercial Space Situational Awareness. Identify government and commercial organizations for transition. Generate the technical and training documentation required for third party integration. Provide services to the government to maximize the utility of the alerts to operations. Provide services to the government to update software prototype for different applications.

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. Applicants 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. Applicants 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 HelpDesk: usaf.team@afsbirsttr.us

REFERENCES:

1) J.-C. Liou and N. Johnson, Earth Satellite Population Instability, Underscoring the Need for Debris Mitigation, NASA, 2006;
2) M. Bolden, Probabilistic Real-time Domain Awareness Leveraging Computer Vision and Computational Intelligence, Pennsylvania State University, 2018;
3) J. Fletcher, I. McQuaid, P. Thomas, J. Sanders and G. Martin, Feature-Based Satellite Detection using Convolutional Neural Networks, Advanced Maui Optical and Space Surveillance Technologies Conference, Maui, HI, 2019;

KEYWORDS: Space domain awareness; computer vision; electro-optical imagery; operator alerting; real-time alerting; computational intelligence; closely space object detection; threat detection; Modeling/Simulation

AF224-0002 TITLE: Novel Architectures for Reduced CSWAP Multidimensional Imaging LiDAR

TECH FOCUS AREAS: Autonomy

TECHNOLOGY AREAS: Sensors; Air Platform

OBJECTIVE: The objective of the project is to investigate new multidimensional imaging LiDAR architectures that simultaneously enable 3-D imaging and scene optical characterization (spectral, polarimetric, other properties) while implementing novel design principles that inherently reduce opto-mechanical complexity. While 3D imaging increases spatial information that can aid in spatial template matching of objects in a scene with a target library, targets in a complex scene, hidden or otherwise, may limit the classification accuracy of spatial template matching. Additionally, in contested battle space, autonomy of weapons systems is attractive as it reduces risk of life to allied forces while increasing threat to opponents. Additional scene/target characterization information would aid in autonomous system target detection/ID. To that end, measurements in additional dimensions (spectral, polarimetric, other) may be useful. One possible set of design principles that enable multidimensional imaging with reduced cost, size, weight, and power (CSWAP) is temporal multiplexing signals instead of the traditional spatial multiplexing of signals as is done with gratings, prisms, and polarization beam splitters. Temporally multiplexed spectropolarimetric LiDAR should be considered as well as other novel approaches.

DESCRIPTION: It is well known that optical properties of surfaces or materials can be used for material ID. This is a common approach used by chemists and biologists to identify chemicals using infrared absorption/transmission spectra. Likewise, polarimetric materials classification through material Mueller matrices has shown promise. A compelling ISR sensor would harness both 3D spatial information and optical characterization information for materials classification and do so in a low CSWAP design that is consistent with the limited CWAP envelope present in missile seekers and UAVs. Traditional approaches to spectral LiDAR employ supercontiumm lasers as the transmitter and a grating/prism in the receiver to spatially disperse spectral signals to a detector array for spectral measurement. Although these systems show promise, the supercontinuum lasers tend to have lower spectral power density and limited grating efficiency that limits range performance. Additionally, spatial dispersion of signals requires free space optics that increases size and a detector array that drives up cost. Traditional polarimetric LiDAR designs transmit a series of pulses, each of which carries a different polarization state, to interrogate a target, the various polarization states are generated by transmitting each laser pulse through a retardation adjustable EO device (rotating retarder, LC retarder, Pockels cell, etc.) Likewise, on the receiver side, each return signal is characterized through a variable polarization analyzer employing a variable retardation and polarizer. This configuration enables measurement of the material Mueller matrix that can be used for classification but comes at the cost of CSWAP, with slow, serial measurements, free space optics, and multiple variable retarders. Although we have focused on spectral and polarimetric measurements, other types of optical characterization may also be useful. It is desirable to develop new configurations that enable rapid (preferably single ~ns pulse) measurement in a low CSWAP architecture. Speed is important, as the LiDAR platform and the target may have relative motion such that serial illumination may not, with high confidence, illuminate the same point in space. One alternative to these traditional approaches is to employ temporally multiplexed architectures. The fundamental motivation is that single pulse based signals dispersed in time, rather than space, may enable rapid, low CSWAP measurements. For example, consider a temporally multiplexed spectral LiDAR system using a cascaded Raman source for illumination.

Through the temporal dynamics of the Raman scattering process, each Raman order will have a unique shape in time, which can allow wavelength identification through temporal measurements instead of spatially dispersed measurements. Now, a single detector measuring temporal shapes can replace a grating/prism and detector array to ID wavelengths. Similar architectures are possible for temporally multiplexed polarimetric LiDAR. Review of literature will illustrate a number of different approaches to temporally multiplexed spectropolarimetric LiDAR. The goal of this solicitation would be to advance low CSWAP architectures capable of multidimensional imaging for improved target detection and ID. Some important system performance metrics are summarized below. Multidimensional imaging can include spectral, polarimetric, or other phenomenology in additional to 3D imaging.

PHASE I: Investigate literature for background information on multidimensional imaging, temporally multiplexed spectropolarimetric LiDAR, and other relevant topics. Identify optical characterization phenomenology and novel architectures that would enable fast, low CSWAP multidimensional imaging LiDAR sensors to aid in operation of autonomous seeker and UAV platforms. Produce systems designs and performance analysis.

PHASE II: Procure hardware to build and characterize proto-type multidimensional imaging LiDAR system. It is desirable that the proto-type system be capable of operation outdoors to enable field data collection campaigns, but it would be acceptable to develop a compelling table top system enabling indoor data collection. If the system is limited to indoor operation, then a path to outdoor operation should be clearly defined. Scan imaging frame rate, field of view, and operational range are metrics of interest. No hardware delivery is required but a demonstration of system hardware is required, system demonstration should include measurement of 3D imaging in conjunction with some other multidimensional phenomenology.

PHASE III DUAL USE APPLICATIONS: Proto-type system is employed for data collection of complex scenes containing various targets and clutter objects. Standard machine learning techniques would be employed to test classification capability.

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. Applicants 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. Applicants 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 HelpDesk: usaf.team@afsbirsttr.us

REFERENCES:

1) LADAR System and Algorithm Design for Spectropolarimetric Scene Characterization, Richard K. Martin, Christian Keyser, Luke Ausley, and Michael Steinke, IEEE Transactions on Geoscience and Remote Sensing, vol. 56, no. 7, pp. 3735-3746, July 2018;
2) Single-Pulse Mueller Matrix LiDAR Polarim, Modeling and Demonstration, Christian K. Keyser, Richard K. Martin, P. Khanh Nguyen, and Arielle M. Adams, IEEE Transactions on Geoscience and Remote Sensing, vol. 57, no. 6, pp. 3296-3307, June 2019;
3) Detection of Hidden Objects Using Passive Polarimetric Infrared Imaging, J. Brown, D. Card, C.

Welsh, C. Saludez, C. Keyser, R. Roberts, IEEE Transactions on Geoscience and Remote Sensing, submitted Aug. 2019;
4) Single-pulse, Kerr-effect Mueller matrix LiDAR polarimeter, C. Keyser, R. Martin, H. Lopez-Aviles, K. Nguyen, A. Adams, and D. Christiodoulides, Opt. Exp. May, 2020;
~~5) Hybrid passive polarimetric imager and lidar combination for material classification, Jarrod P. Browna, Rodney G. Roberts, Darrell C. Card, Christian L. Saludez, and Christian K. Keyser, Opt. Eng. Aug. 2020;~~
6) Temporally Multiplexed Multi-Spectral LADAR with Raman-Based Waveforms, Luke Ausley, Rick Martin, and Christian Keyser, SPIE Defense and Commercial 2018;
~~7) Anomaly detection of passive polarimetric LWIR augmented LADAR, Jarrod P. Brown, Rodney G. Roberts, Chad M. Welsh, Darrell Card, and Christian Keyser, SPIE Defense and Commercial 2018;~~
8) Single-Pulse Mueller Matrix Polarimeter Laboratory Demonstration, Arielle Adams, Christian Keyser, Khanh Nguyen, and Rick Martin, IEEE RAPID conference, 2018;
9) Spectral-based Expansion of Temporally Multiplexed Multispectral LADAR with Raman Waveforms, Luke Ausley, Rick Martin, and Christian Keyser, IEEE RAPID conference, 2018;
10) Compact LiDAR Polarimetry via Time-Varying Transmit Polarization and an Elliptical Polarization Analyzer, Richard K. Martin and Christian Keyser, SPIE Defense and Security, 2019, Maryland;
11) A fiber Kerr effect polarization state generator for temporally multiplexed polarimetric LADAR, Arielle Adams, P. Khanh Nguyen, Chrisitan Keyser, and Demetri Christodoulides, SPIE Defense and Security, 2019, Maryland;
12) Optical Pulse Generation with Versatile Time-Varying Polarization States, H. E. Lopez Aviles, C. K. Keyser, R. K. Martin, K. Nguyen, A. M. Adams, D. N. Christodoulides, CLEO, May 2020;
13) Diagonal Mueller Matrix measurements based on a Single Pulse LiDAR Polarimeter, Chad Welsh, Stefano Roccasecca, Khanh Nguyen, Richard Martin, Christian Keyser, SPIE DCS 2020;

KEYWORDS: LiDAR classification; autonomy; material classification; machine learning; spectral classification; Mueller matrix classification

AF224-0003 TITLE: 20 MW Microwave Source Set with C- to Low K-Band Coverage

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Tool suite that supports the counter-electronics mission of MAJCOM's by enabling the identification of target vulnerabilities to high power microwave (HPM) waveforms. The DoD is currently investing significant resources across the services to develop and deploy counter-UAS and other technologies. A robust national effort and Community of Interest (CoI) exist between the Air Force Research Laboratory, Naval Research Laboratory, Sandia National Laboratory and Army Research Laboratory to develop and deploy HPM technologies and understand the effects interactions and optimizations regarding range, pulse width, repetition rate, and frequency.

DESCRIPTION: Develop proof of concept, internally test, and subsequently deliver a microwave source set that produces 20 MW, maximizes C- to low K-band coverage (4-20 GHz), microwave pulse width adjustability 10 ns-1 µs, and up to 1 kHz repetition rate. This set may consist of tunable oscillators, amplifiers, etc. Due to the challenging nature of this topic, not all of these desired parameters may be possible to meet and are not necessarily required to be selected, e.g. it may only be feasible to cover 1 or 2 frequency bands--meeting, or nearly meeting, the power requirement is the most important. The planning, design, and deliverables should include pulsed power and any prime power subsystems that go beyond grid power. Generated microwave output shall feed into standard in-band rectangular waveguide; waveguide power handling (vacuum breakdown) may limit output power at the higher frequencies.

PHASE I: Demonstrate proof of concept; virtual prototypes (or design configuration details using commercial products) of microwave oscillators, mechanically or electronically tunable oscillators, amplifiers, etc. that achieve 20 MW in C- to low K-band and microwave pulse width and repetition rate adjustability. Include detailed design plan/description for the source(s), pulsed power, prime power, pulse-width control, breakdown avoidance, testing/safety, etc. that will be needed in Phase II demonstration. Pulse width control may employ plasma switches, pulse-forming line adjustability, etc. A systems-level engineering approach is required during this phase to analyze and demonstrate interoperability between the components - pulsed power, source, pulse-width control, etc. to account for voltage/waveform effects, feedback, and reflections and to reduce risk in Phase II. Maximum desired (not required) shot to shot variations at any given setting are pulse width 5-10%, frequency 1-5% from center frequency, and power 5-15%.

PHASE II: Deliver and demonstrate microwave suite after fabrication, acquisition, assembly, internal testing, etc. to AFRL Kirtland AFB test facility. The demonstration will require timely coordination with the AFRL test schedule and will involve free-field radiation via AFRL's in-band rectangular waveguide antennae into an RF anechoic chamber. Radiated power, pulse width adjustability, frequency, and repetitive firing rates will be confirmed with field probes at set distances from the antenna aperture. These coordinated tests may or may not be used to gather electronics effects data.

PHASE III DUAL USE APPLICATIONS: Mature the microwave tool suite for the end user and in compliance with regulations. Pursue commercialization. Should the small business only be capable of covering a fraction of the frequency bands and other parameters in Phase I and II, there may be interest by AFRL and/or other HPM Effects members in acquiring additional sources and components that more-fully cover the parameter space. In addition, there may also be interest in using these potentially compact, light-weight, frequency/waveform-agile (or phase-controllable) sources in the 20 MW range for counter unmanned aerial vehicle (C-UAS), base defense, aircraft defense, and other missions in the DoD.

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KEYWORDS: high power microwaves; electromagnetic; RF; directed energy; effects; vacuum tube; solid state; source

AF224-0004 TITLE: X-Band RF Linear Accelerator

TECH FOCUS AREAS: Directed Energy; Nuclear

TECHNOLOGY AREAS: Nuclear; Electronics

OBJECTIVE: Deliver a compact, high current X-band RF linear accelerator to the Air Force Research Laboratory. This accelerator should be capable of accelerating a DC beam from an electron gun. The peak beam current should be approximately 75 mA/250 mA (threshold/objective) averaged over a 3 us/10 us (threshold/objective) macropulse, as measured after an exit window. The electron gun and accelerator should be 1 m or smaller in length. The beam energy should be 5 - 15 MeV (preferably tunable). No repetition rate is specified.

DESCRIPTION: Work should include extensive modeling and simulation of the accelerator design and RF source (if building in-house). This should include GEANT simulations or other electron propagation modeling tools and electromagnetic modeling software such as CST, HFSS, or other suitable tools. This should include an analysis on performance at different charge levels to indicate performance while accelerating a current-modulated pulse train. Those advancing to Phase II will need to fabricate the source and check out its performance. This is to include cold tests to verify the frequency of the accelerator and the fill time. Final beam acceleration tests can be performed at AFRL's facilities and will include measurements of beam current, pattern, and energy. Those advancing to Phase III will need to assist AFRL in the integration of a wideband buncher, integration into a platform, and/or improvements to system performance.

PHASE I: Phase I awardees should design and simulate a suitable X-band linear accelerator to meet the Topic Objectives, as described above. Ideally this accelerator will be tunable from 5-15 MeV, either through RF power adjustment or adding/subtracting modular accelerating segments. This should include an electromagnetic analysis and an electron propagation analysis, with emphasis on performance with different electron bunch charges. The capture coefficient should be higher than 50%. The emittance at the accelerator exit window should be less than 200 pi 10^-6 m rad. Identify a suitable commercial off the shelf electron gun, pulsed power, and X-band RF source to fill the accelerator, or design and simulate an in-house system(s). Fabricate one accelerator cavity to demonstrate feasibility of design. Provide quarterly reports to AFRL and write a final Phase I report presenting the accelerator and RF source design and all modeling and simulation work (including raw data) indicating the device's progress towards meeting Topic Objectives. Provide a plan to carry out Phase II.

PHASE II: Phase II awardees should fabricate their accelerator designs and purchase or fabricate their identified electron guns, pulsed power sources, and X-band RF sources. Tests should be carried out to demonstrate the performance of the accelerator and compare to expected results. Final tests to accelerate electron beams may be performed at AFRL's facilities. Quarterly reports should be sent to AFRL. A final report should be written to include accelerator performance and data, standard operating procedures, troubleshooting tips, and a plan for completing Phase III.

PHASE III DUAL USE APPLICATIONS: During Phase III, awardees will assist AFRL in integrating a custom pre-buncher (to be designed and built separately) into the accelerator. The system may also be integrated onto a mobile platform for field testing. Finally, improvements to system performance may be required. Quarterly reports to AFRL will be required. A final report to be delivered to AFRL will be required which will include a summary of all work performed as a part of Phase III.

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3) Diomede, M., et. al, Preliminary RF Design of an X-band linac for the EuPRAXIA@SPARC_LAB project, 2021;
4) Mishin, A. V., Advances in X-Band and S-Band Linear Accelerators for Security, NDT, and Other Applications, 2005.

KEYWORDS: Linear accelerator; RF Linac; Electron Beams; Directed Energy

AF224-0005 TITLE: High Brightness Mid-IR Laser Illuminator

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Electronics

OBJECTIVE: A turnkey laser source capable of emitting 20W average power, 4-5µm wavelength with near diffraction limited output using an array of semiconductor lasers such as Quantum Cascade Lasers for use in defense tracking illumination and remote sensing applications.

DESCRIPTION: Current state of the art mid-IR semiconductor lasers can provide only up to a few watts of output power. In order to reach higher power, a method of beam combination or amplification is needed. The Government would like to see which approach is most feasible and efficient to produce an end product that can produce minimal of 20W output power at mid-IR spectral range (4-5µm) with diffraction limited beam quality.

PHASE I: The topic requires design and proof of concept of laser source capable of producing 20W output power at 4-5µm wavelength with diffraction limited beam quality. It shall be capable of operating pulse width range from 1µs up to continuous wave. The proposer shall demonstrate feasible power scaling and/or beam combining approach with output beam quality less than 2

PHASE II: Requires implementation and construction the proposed design during Phase I - a laser source capable of producing 20W output at 4-5µm wavelength with diffraction limited beam quality. Prototype shall be capable of operating pulse width range from 1µs up to continuous wave. Requires demonstration of power scaling and/or beam combining method of the laser source with greater than 20W output power and less than 2 beam beam quality factor.

PHASE III DUAL USE APPLICATIONS: Requires reducing cost of the laser source with streamline system production. The interface shall be development with end-user's requirements, including integration with users' systems and reduction of size, weight, and power to meet user needs.

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REFERENCES: 1) www.forwardphotonics.com/products

KEYWORDS: high brightness laser source; mid-IR semiconductor laser; quantum cascade laser; beam combination

AF224-0006 TITLE: High Power Microwave Applications for Water Conservation

TECH FOCUS AREAS: Biotechnology Space; Directed Energy

TECHNOLOGY AREAS: Bio Medical; Space Platform

OBJECTIVE: Develop a compact high power microwave system outputting a very high power burst of energy in a narrowband and tunable frequency region, which will demonstrate the viability of High Power Electromagnetics to conserve water resources in austere conditions. Perform spectrum agile high-power and short-interval transmissions to break down molecular structure of target organisms to promote the reuse and/or conservation of water. The defense industry leverages various incarnations of these technologies for directed energy weapons and seeks to demonstrate the application of these efforts to maintaining dominance in increasingly austere conditions.

DESCRIPTION: The primary focus of this topic is to identify and demonstrate ways in which HPM can be used to greatly reduce water consumption for forward operating locations in austere conditions. HPM can be used to sterilize medical or military equipment, seed germination and can be used to for non-potable water treatments giving rise to the opportunity for reuse. The objective is to demonstrate viable applications in these areas for which the armed services can take advantage for future battle missions. Successful technology development should result in a high-power source, coupled to an antenna with directivity. Integration of this system must be designed into a transportable, standalone capability. The proposer should describe HPM and EW narrowband sources and associated antenna performance parameters in terms of frequency, bandwidth, effective radiated power (ERP), duty cycle/factor, efficiency, and directivity. The interest is broader than effects of HPM against water-borne contaminants and seeks to pursue applications where microwaves can be used to limit water consumption and/or promote reuse.

PHASE I: Identify efficiencies that either limit water usage or promote the reuse of water resources by targeting the breakdown of molecules for several candidate architectures (seeds, waste, nonpotable water). Develop concepts that illustrate a proof-of-concept design. This should include details that 1) describe how the design(s) demonstrate manufacturability, 2) address how technical challenges would be addressed, 3) information on how concepts may be reasonably scaled to accommodate high volume throughput. Include methodology and potential prototype performance that will demonstrate the proposed concept with the output pulse parameters as described. Conduct a sub-scale component demonstration. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop detailed designs for a prototype system that improves performance parameters that meet system requirements as specified in the Description. Demonstrate a prototype system, according to this design, that meets threshold parameters at a minimum. At an AF test facility demonstrate that the prototype delivers, or is scalable to deliver, the requisite power and RF spectrum to allow the reuse or conservation of water resources. Prototype Delivery to AFRL. Report performance results.

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 water conservation systems to be used in research laboratories within gov’t agencies, national laboratories, academic laboratories, and other research institutions.

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3) Gururani, P., Bhatnagar, P., Bisht, B. et al. Cold plasma technology, advanced and sustainable approach for wastewater treatment. Environ Sci Pollut Res 28, 65062â€“65082 (2021);
4) https://technology.nasa.gov/patent/MSC-TOPS-53#:text=Test%20results%20show%20that%20exposing,within%20a%20water%20filtration%20system

KEYWORDS: directed energy; DE; water conservation; HPM; High Power Microwave; High Power Radio Frequency; HPRF

AF224-0007 [Topic Removed]

AF224-0008 TITLE: Digital Multisensory Augmented Reality for Special Warfare (DMARS)

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a low-latency multisensory digital helmet-mounted near-to-eye augmented reality system for use by dismounted special warriors. System must provide multispectral vision in night, day, and all-weather operations.

DESCRIPTION: The Air Force has a mission need for digital visual augmentation systems. The Digital Multisensory Augmented Reality for Special Warriors (DMARS) system sought is a dual-band visualization device primarily for night operations. Architectures of interest include monocular helmet-mounted with dual imaging sensors: one high-resolution reflective-band scene understanding image (in-line with eye); and one low-resolution emissive-band imager above eye (for overlay or salient extraction). Other architectures (hand-held, split component/off-body mounting, binocular) are also of interest. Both sensor bands must be usable as vision aides during day, night (including overcast starlight), and all-weather operations. Reflective bands require a light source (sun, moon, stars, artificial) and include the visible (400-700 nm, near infrared (625-930 nm) and shortwave infrared (0.9-3.5 um). Emissive (aka thermal) bands include midwave infrared (3-6 um) and longwave infrared (7-15 um). Architecture should enable expansion to include other sensory modalities (audio, tactile). The DMARS device shall be battery powered and be capable of displaying symbology/imagery from an external source (aka end user device). The size, mass, mass distribution, and power consumption should be minimized sufficiently to achieve user acceptance. The device should be comfortable for wearing under combat conditions for hours. Performance metric threshold (objective) sought include, reflective sensor band 2000x2000 px (4000x4000 px); emissive band 640x512 px (1280x1024 px); field-of-view 40x40 deg. (80x80 deg.); frame rate 60 Hz (200 Hz); latency from objective-to-eye, 17 ms (1 ms); head-born mass 1 kg (0.5 kg); head-born moment arm 0.1 kg-m (0.05 kg-m); power 6W (2W); volume 1000 cc (500 cc); and head-mounted battery time 4 hr (8 hr). No government furnished materials, equipment, data, or facilities will be provided.

PHASE I: Design a DMARS system with size, weight, and power (SWaP) consistent with head-worn implementation. Estimate all performance metrics via laboratory experiments and analyses. Develop a system architecture for DMARS integration into the dismounted special warrior kit. Develop a System Implementation Plan for evaluating DMARS operating performance in combat environments, including producibility and supportability.

PHASE II: Fabricate prototype DMARS at TRL6. Evaluate prototype in laboratory and representative environments. Incorporate mechanical, electrical, and software interfaces required for integration into fielded BAO kits. Support operator testing, provide special test equipment, and refine prototype performance based on feedback. Deliver prototype optimized for SWaP performance, reliability, and ruggedization consistent with dismounted warfighter operations. Provide bill of materials. Create roadmap to mature technology to TRL8/MRL8.

PHASE III DUAL USE APPLICATIONS: Develop, fabricate, and deliver Qty(6) DMARS production-configuration units at TRL8/MRL8 with interfaces to the fielded BAO Kit. Establish DMARS performance specification. Provide bill of materials. By the end of Phase III, the DMARS should be capable of all-weather operation worldwide. Evaluate DMARS and its subsystems for other special operations applications.

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KEYWORDS: Augmented Reality; Monocular; Near-to-Eye; Multisensory; Reflective Band; Emissive Band; Special Warriors; Digital

SF224-0009 TITLE: Novel Metrology Solutions for Space Based Antennas

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Develop and demonstrate technology capable of providing advanced metrology for large space-based antenna arrays.

DESCRIPTION: Large space-based antenna arrays are projected to be needed for future space missions. There is a need to assess the performance, health and degradation of large antenna arrays. For this reason, this topic seeks novel metrology solutions for space-based antennas. As large structures are built in space, the large size presents several design challenges. Orbital forces can cause the antenna elements to move, bend or flex in small, but tangible amounts that affect the performance of the individual antenna elements as well as the entire array. Likewise, the electronics that controls the antenna elements are subject to the same stresses and strains inherent within the operational space environment that may degrade or even damage these components. A novel metrology solution is sought, such as those that focuses on measuring the electromagnetic emissions of the elements to determine and assess in-situ that their performance is within the expected parameters. The solution must be able to assess the in-band performance of the elements themselves by measuring the sidebands, scattering, etc. as well as the out-of-band emissions from the elements, interconnects and active electronics that control the elements. The sensor design must be ultra-lightweight to meet space Size Weight and Power (SWaP) requirements. It must be capable of capturing emissions at greater than 170 dBm sensitivity while still maintaining adequate dynamic range to function near a high-power antenna array. The sensor must have broadband collection capability to assess both in-band and out-of-band emissions and have the Radio Frequency (RF)/microwave collection capability and processing tightly integrated to achieve the required performance.

PHASE I: During the Phase I effort, a prototype system will be developed to demonstrate the technical feasibility for a sensor and antenna configuration for novel metrology of space-based antennas.

PHASE II: Complete development of a prototype system determined to be the most feasible solution. During the Phase II, a system will be demonstrated that is capable of automatically and accurately identifying performance anomalies and degradation of an antenna array, individual antenna elements and electronics that control the array.

PHASE III DUAL USE APPLICATIONS: The contractor will transition the adapted non-Defense commercial solution to provide expanded mission capability to a broad range of potential Government and civilian users and alternate mission applications.

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KEYWORDS: Space-based Antenna Arrays; Electronic Degradation; Performance Measurement; Electronic Health Assessment

SF224-0010 TITLE: On-Orbit Assembly and Manufacturing for Space-Based Antennas

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Demonstrate a manufacturing or assembly system that can function on Earth, in partial gravity, or without gravity. The system should be able to create spacecraft or space station components in space, on asteroids, or on planets. The manufactured components may comprise primary structures, pressure vessels, and antennae, among others. Specifically for antennae, a truss-like primary structure will need to be manufactured and assembled. Then the antenna will need to be manufactured onto the truss system. The truss and antenna need to be recapturable after deployment. The truss and antenna need to be repairable and reconfigurable for different frequencies.

DESCRIPTION: Problem Description and Benefit, Spacecraft engineering spends ~75% of its man-hours designing systems to survive launch. Less than 25% of spacecraft engineering man-hours is spent on mission specific design and manufacturing. The "Tyranny of Launch" and the "Tyranny of the Fairing" severely limit the efficiency and scale of what may be performed on-orbit. For example, unfurlable antenna systems take years to design, test, and validate; and they are used only once during a decades long mission. Unfurlable mechanisms may be deleted from the orbital engineering lexicon, if On-Orbit Manufacturing and Assembly are used instead. The aperture size of orbital systems may also be greatly increased, if On-Orbit Manufacturing and Assembly are used to distribute the antenna lift operation over multiple launches. After a Micro Meteor Orbital Debris (MMOD) collision, the truss/antenna system may be repaired, if On-Orbit Servicing is designed in. Therefore, On-Orbit Servicing Assembly and Manufacturing (OSAM) may create a lower cost, more resilient, and higher performance antenna system than ever before. OSAM also allows for the creation of pressure vessels that are too big for launch. Engineering firms may also design spacecraft after the factory itself has been launched. The OSAM reordering of launch and manufacturing operations will 4X the engineering manpower of the aerospace firms, dramatically increasing the rate of evolution of spacecraft systems.

PHASE I: During the Phase I effort, a prototype system will be developed to demonstrate the technical feasibility On-Orbit Servicing, Assembly, and Manufacturing of space-based antennas.

PHASE II: Large scale, autonomous manufacturing or assembly demonstration of the antenna system. The system will be built larger than the biggest unfurlables. Systems such as airbearings and cable-trapeze suspension in a highbay may be employed.

PHASE III DUAL USE APPLICATIONS: The contractor will transition the adapted non-Defense commercial solution to provide expanded mission capability to a broad range of potential Government and civilian users and alternate mission applications.

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KEYWORDS: Space-based Antenna; OSAM; Robotics; Manufacturing; Assembly; Truss, Engineering

AF224-0011 TITLE: Software-Defined Networking (SDN) enabled Satellite Bandwidth on Demand

TECH FOCUS AREAS: Network Command, Control and Communications; 5G; Autonomy

TECHNOLOGY AREAS: Information Systems; Space Platform

OBJECTIVE: Develop proper interfaces, solution architectures and requirements needed to support the software-defined networking (SDN)-based flexible satellite bandwidth on demand Advance typical satellite broadband access services with customers to be able to dynamically request and acquire bandwidth and quality of service (QoS) in a flexible manner.

DESCRIPTION: Nowadays, many user demands from US military, commercial, and allied/international partners may need transient satellite communication resources during specific periods. These transient resources can be utilized from particular satellite constellations in different orbit regimes (e.g., low-, medium-, and geosynchronous earth orbits) to access best reception, or the least utilized network or other conditions, and thus leading to higher application performance and business efficiency for particular situations. This topic call seeks elastic network resource provision enabled by SDN implementations for flexibility and agility. It includes the necessary traffic control, inspection, prioritization and metering capabilities present across the satellite network components. Solutions on flexible on-demand bandwidth that intelligently integrate a SDN architecture with a programmable northbound application programming interface to cost-effectively provide guaranteed performance on a per-connection or flow basis to meet service level agreement requirements are of interest under this call. Moreover, potential approaches for SDN implementations should be achievable across multi-band and multi-orbit satellite networks, including satellite hubs and terminals. Other challenges are of interest in the context of sharing and multi-tenancy operational environments, involving business and operation service support for military, commercial, and allied/international partners, e.g., dynamic service level agreements, dynamic traffic control, and configurations of different QoS profiles and service classes.

PHASE I: Develop a use case comprised of broadband connectivity between multiple fixed and/or mobile satellite user terminals dispersed across a region of interest and two or more commercial satellite service providers that allows for SDN techniques be applied and supported by satellite gateways and remote satellite terminals to meet flexible and on-demand bandwidth requirements. Analyze key technical challenges on how to provide transient on-demand network services without affecting normal operations of other users and to perform fast provisioning of satellite network resources and to perform dynamic network configurations to meet demands.

PHASE II: Demonstrate a proof of concept for SDN-based flexible satellite bandwidth on demand. Evaluate multi-band and multi-orbit satellite broadband access services with customers to be able to dynamically request and acquire bandwidth and QoS in flexible manners. Document agility metrics pertaining to satellite network configurations in real-time (or near real-time) to better fulfil customer expectation but also to optimize utilization of network resources.

PHASE III DUAL USE APPLICATIONS: Integrate with prospective follow-on transition partners to provide improved operational capability to a broad range of potential Government and civilian users and alternate mission applications. Government organizations such as Air Force Research Laboratory and Space Systems Command could sponsor a government reference design in collaboration with small business and industry partners. Successful contractor technology demonstrations will inform the technical requirements of future acquisitions by Primes and subcontractors.

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KEYWORDS: network resource provision; software defined networking; dynamic traffic control; configurable traffic prioritization; guaranteed performance; service level agreements; multi-tenancy operational environments; quality of service profiles; service classes

SF224-0012 TITLE: Customer Functions Virtualization over Satellite Terminals

TECH FOCUS AREAS: Network Command, Control and Communications; 5G; Autonomy

TECHNOLOGY AREAS: Information Systems; Space Platform

OBJECTIVE: Develop network function virtualization (NFV) enabled satellite terminals for optimized content distribution. Integration with other terrestrial networks in a dynamic and flexible manner as part of overall 5G ecosystems. 5G-enabled orchestration of warfighting missions to anti-fragile agility of differentiated communication services to hybrid terrestrial-satellite network supports with warfighting quality of experience.

DESCRIPTION: Satellite terminals that deliver satellite broadband access are typically equipped with an IP router and/or an Ethernet switch to interwork with any attached external end-user equipment. The network equipment on the user side (e.g. routers, switches, firewalls, etc.) used to connect the end-user hosts to the satellite terminal is collectively referred to as the customer premise equipment. Central to any quality of service and quality of experience increases delivered to end users is the virtual network function as a service (VNFaaS), where virtual network appliances dynamically offered by satellite network operators to customers are in the form of network function virtualizations (NFVs); e.g., load balancers, traffic steering, gateway functionalities, media storage and processing, etc. The traditional provision in multi-tenant way; i.e., per customer of such capabilities is currently very expensive, making practically network functionalities at satellite gateways to apply to entire traffics and of course not being manageable by customers. An important aspect of using NFV capabilities effectively and affordably for dual civil and defense purposes is the instantiation at NFV-enabled satellite terminals. In this case, it is advantageous to accommodate interactions with customers, allowing them to select, deploy, manage and monitor NFVs according to their needs. This call seeks a proof of concept to enable a plethora of choices for applying traffic steering of media services, optimized content distributions, or performing dynamically adaptation or other combined actions depending on the problem and the way of resolving it. Solutions that are capable of deploying and instantiating dynamically NFVs to facilitate the provision of the requested media services while aiming to maintain the appropriate quality of experience are of interest under this call. Solutions that can quickly deal with the congestion with an appropriate instantiation as it adapts the content dynamically in order to facilitate its provision are highly encouraged.

PHASE I: Identify scenarios and use cases where the adoption of NFV technologies into satellite terminals is seen as a key enabler towards more flexible and agile integration of satellite and terrestrial networks. Conceptualize the support of service composition and service chaining of various VNFs performed at the federation layer for satellite core networks, satellite network management, satellite hubs, and hybrid satellite terminal and customer premise equipment.

PHASE II: Demonstrate the utility of flexibility and reprogrammability in VNFaaS placement logic for selecting appropriate NFV instantiation point of presence per service and action types. Evaluate coordination logic for federation decisions to support instantiations and deployments of VNFaaS. Demonstrate a proof of concept for multi-mission orchestration of the VNFaaS lifecycle through appropriate monitoring and adaptation framework reassuring guaranteed service delivery.

PHASE III DUAL USE APPLICATIONS: Integrate with prospective follow-on transition partners to provide improved operational capability to a broad range of potential Government and civilian users and alternate mission applications. Government organizations such as Air Force Research Laboratory and Space Systems Command could sponsor a government reference design in collaboration with small business and industry partners. Successful contractor technology demonstrations will inform the technical requirements of future acquisitions by Primes and subcontractors.

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KEYWORDS: network function virtualization; satellite terminals; virtual network function as a service; satellite network operators; load balancers, traffic steering; satellite gateways and hubs; optimized content distribution; hybrid satellite terminal and customer premise equipment; network function virtualization instantiation; coordination logic; federation layer

AF224-0013 TITLE: Advanced Ceramic Electrochemical Cell for Oxygen Production

TECH FOCUS AREAS: Biotechnology Space; Microelectronics

TECHNOLOGY AREAS: Bio Medical; Materials

OBJECTIVE: Develop and demonstrate an advanced oxygen conducting ceramic electrochemical cell and multi-cell stacks capable of increased production of pure (≥99.9%) pressurized oxygen using electric power and air.

DESCRIPTION: Aircraft On-Board Oxygen Generating Systems (OBOGSs) use molecular sieve and pressure swing adsorption technology. This technology is highly dependent on source air pressure. Source air on newer aircraft is limited due to the increasing aircraft subsystem demands for cooling air. The source air (bleed air or environmental control system air) can have significant low pressure transients and these conditions can cause OBOGS oxygen and flow performance issues. An advanced oxygen conducting ceramic electrochemical cell with increased oxygen production (≥1 liter/minute per cell) is needed for this solid state technology to compete effectively with existing OBOGS technology. Current ceramic electrochemical cells produce oxygen at the rate of about 0.1 liter/minute per cell. This solid state technology would not be impacted by source air pressure variations. Further, the device would have no moving parts and operate using electric power. The electric power would ionize oxygen in the air, conduct the oxygen ions through the ceramic membrane, and then the ions would recombine to form pure pressurized oxygen. The membrane only transports oxygen ions, hence, oxygen would be contaminant free. The effort will, 1) develop improved ion conducting membrane material or a new composition of an existing material; 2) develop an advanced oxygen conducting ceramic wafer or cell; 3) fabricate and demonstrate state-of-the-art electrochemical cells capable of producing pure (≥99.9%) pressurized oxygen at (≥ 1 liter/minute per cell; and 4) develop and demonstrate a multiple cell stack device capable of producing oxygen at a total flow rate of 30 liters/minute. The electrochemical cell characteristics would be assessed based on oxygen purity, production flow rate, pressure, start-up time, size, and weight. The desired outcome will be to demonstrate a new state-of-the-art ceramic electrochemical cell and assess its viability for use on future aircraft OBOGS.

PHASE I: For the phase I effort, new materials and new compositions of existing materials will be identified, researched, and analyzed to assess their ability to achieve increased flow rate (≥1 liter/minute per cell) of pure (≥99.9%) oxygen at pressures of ≥300 pounds per square inch gauge. Material properties will be assessed to predict the material most likely to achieve desired performance. A final report will be provided summarizing the materials considered, material properties, and probability the materials will meet the desired objectives.

PHASE II: Advanced ceramic electrochemical cells will be fabricated and evaluated. The most viable electrochemical cell will be demonstrated and then incorporated into a multi-cell stack. The goal of the integrated stack is to achieve a total flow of 30 liters/minute of ≥99.9% oxygen at a pressure of ≥300 pounds per cubic inch gauge. The stack will be demonstrated and the results of the effort will be summarized in a final report.

PHASE III DUAL USE APPLICATIONS: The advanced electrochemical cells and stacks will be incorporated into an oxygen generator breadboard able to produce 60 liters/minute of ≥99.9% oxygen at a pressure of ≥300 pounds per cubic inch gauge. The dimensions of the breadboard should not exceed 24 inches in length, 12 inches in height, and 12 inches in width. The weight of the breadboard should

not exceed 60 pounds. This technology could also be used to supply oxygen for medical applications.
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KEYWORDS: ceramic electrochemical cell; solid electrolyte oxygen separator; oxygen generation; ceramic oxygen generator; ion transport membrane

SF224-0014 TITLE: Energy Harvesting

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Three percent (3%) beginning of life (BOL) minimum average energy harvesting device efficiency that enables higher system efficiency in 2022. 4% minimum average device efficiency that enables higher system efficiency in 2024. 6% minimum average device efficiency that enables higher system efficiency in 2027.

DESCRIPTION: Space Force is focused on target signature reduction for satellite resiliency and is moving from the present baseline of large, 5-7 ton GEO satellites replenished every 15 years, to small satellites, with reduced target signatures, in all orbits replenished every 3-5 years to utilize swarming attack methodologies and sustain a technology lead over U.S. adversaries. Space Force programs typically require 3-5% more relative power for every mission block and spiral. Using 32% solar cell efficiency as a benchmark, approximately 68% of solar power is shed as waste heat. State-of-practice terrestrial energy harvesting devices, with TRL 9, 3% conversion efficiency, could either (1) improve total spacecraft power in smaller envelopes or (2) provide smaller thermal and optical signatures to the adversary. Using today's state-of-practice values for energy harvesting devices, if the 68% (de-rated to 58% for reflection) of wasted solar energy is converted to electrical power, then a 3% efficient energy harvesting device could generate a maximum of 2% efficiency from incident solar power (.58 x .03 = .02).

PHASE I: Demonstration of device efficiency. Develop engineering model for system implementation.

PHASE II: Late development of energy harvesting device and coupon level performance demonstration.

PHASE III DUAL USE APPLICATIONS: Prototype development and on orbit demonstration.

REFERENCES: 1) Landis, Geoffrey presentation at Aerospace Corporation April 2021 Space Power Workshop (Energy Harvesting Devices)

KEYWORDS: Energy Harvesting; Photo-voltaic; Seebeck effect; thermoelectric (TE); thermocouples; thermopile; thermo-radiative (TR); or thermal photo-voltaic (TPV)

AF224-0015 TITLE: Forward Error Correction Codes for Ultra-Reliable Low-Latency Global Navigation Satellite Systems (GNSS) Signals

TECH FOCUS AREAS: Autonomy; General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Advance the state-of-the-art in forward error corrections (FEC) for improved performance and responsiveness in signals to address real-time threats and challenging urban fading environments through the development of short and very-short block length FEC regimes which would ultimately result in a near-capacity theoretical performance limits.

DESCRIPTION: The US Space Force has identified advanced signals as potential GPS modernization investments as they would offer enhanced capabilities in signal responsiveness in dealing with real-time threats, robust satellite navigation performance in urban fading environments, and efficient use of available spectrum. As both military and commercial sectors demand for faster and higher capacity GNSS applications, there have not been any design guidelines and standards to construct finite-length FEC designs, especially in the short and very short block-length schemes with low-latency and low-decoding complexity. In the effort to optimize performance on target of near capacity information-theoretical limits, there is much interest in pursuing innovative, robust, and scalable solution to simple yet powerful coding schemes and low complexity decoding algorithms for ultra-reliable performance. Current areas of interest include but are not limited to the following, i) short and very short block-length error correction codes and fundamental limits; ii) signal processing techniques and fast algorithms that are directly beneficial in the L-band and urban multi-path fading environments; and iii) FEC code designs and fundamentals under non-orthogonal multiplexing multicarrier broadband GNSS applications.

PHASE I: Establish feasibility of the proposed solution. Perform sufficient modeling and/or experimentation to determine fundamental tradeoffs between frame error rates and block lengths of the proposed set of short and very-short block-length FECs. Evaluate performance of both code and signal designs for ultra-reliable low-latency GNSS subject to urban wireless fading channels. Establish a preliminary design leading for Phase II.

PHASE II: Finalize design of a demonstration prototype. Experiment with both software-defined radio transmitter and user equipment (UE) to demonstrate the ability to timely adapt very-short block-length FECs in feedback and/or pre-emptive manners. Evaluate flexibility and reprogrammability to affordably and effectively reconfigure adaptive very-short block-length FECs for different environments, including urban canyon, foliage canopy and diverse elevations. Consider ease of installation or deployment and sustainment costs. Contact potential customers and establish a transition plan with partners supporting Phase III activities.

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: Global Navigation Satellite Systems; very-short block-length error correction codes; user equipment; near-capacity information theoretical limits; L1C; urban fading environments; low complexity decoding; ultra reliable; low latency