VERSION 3

DEPARTMENT OF THE AIR FORCE
24.B SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) Phase I
PROPOSAL SUBMISSION INSTRUCTIONS

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. **Offerors must ensure proposals meet all requirements of the STTR 24.B BAA posted on the Defense SBIR/STTR Innovation Portal (DSIP) at the proposal submission deadline date/time.**

Applicants are encouraged to thoroughly review the DoD Program BAA and register for the DSIP Listserv to remain apprised of important programmatic and contractual changes.

- The DoD Program BAA is located at: https://www.defensesbirsttr.mil/SBIR-STTR/Opportunities/#announcements. Be sure to select the tab for the appropriate BAA cycle.

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, “24.B 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. All applicants have ample opportunity to request clarifying information. **The DAF encourages applicants to request clarifying information as early as possible, as delays in such requests constrain the DAF’s ability to provide satisfactory resolution to applicant concerns.**
- 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 SBIR 24.B BAA.
- Air Force SBIR/STTR Contracting Officer (CO):
    - Mr. Daniel J. 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 STTR 24.B 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.

PHASE I PROPOSAL FORMAT

Complete proposals must include all of the following:
Volume 1: DoD Proposal Cover Sheet

Note: 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 this section.

Volume 2: Technical Volume
Volume 3: Cost Volume
Volume 4: Company Commercialization Report
Volume 5: Supporting Documents
Volume 6: Fraud, Waste, and Abuse Training

DoD PROPOSAL COVER SHEET (VOLUME 1)

Complete the proposal Cover Sheet in accordance with the instructions provided via DSIP. The technical abstract should include a brief description of the program objective(s), a description of the effort, anticipated benefits and commercial applications of the proposed research, and a list of keywords/terms. The technical abstract of each successful proposal will be submitted to the Office of the Secretary of Defense (OSD) for publication and, therefore, must not contain proprietary or classified information.

TECHNICAL VOLUME (VOLUME 2):

The Technical Volume should include all graphics and attachments but should not include the Cover Sheet, which is completed separately as Volume 1. The Phase I technical volume (uploaded in Volume 2) shall contain the required elements found below. Ensure that all graphics are distinguishable in black and white.

The Phase I Technical Volume page/slide limits identified for the topics 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.

These instructions supplement the 24.B STTR BAA. In addition to the requirements found in the 24.B STTR BAA, applicants are required to provide the following information in Volume 2:

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. Only one principal investigator/project manager can be designated to a proposal at any given time.
- 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 Statement of Work Outline
NOTE: The DAF 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 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 (VOLUME 3)
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.-g. below) regarding funds use. The DSIP Cost Volume and Itemized Cost Volume Information will not count against the specified page limit. The itemized listing also may be submitted in Volume 5 under the "Other" dropdown option.

a. **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.

b. **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.

c. **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 for the CO to determine whether these hours, fringe rates, and hourly rates are fair and reasonable.

d. **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.

e. **Subcontracts**: Involvement of consultant in the project's planning and/or research stages may be appropriate. If so, describe in detail and include information in the Cost Volume. A minimum of 40% of each STTR project must be conducted by the SBC and a minimum of 30% of the effort performed by the single partnering Research Institution. Deviations from these performance of work requirements are not permitted. The STTR 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. Additionally, see DoD SBIR 23.3 BAA for more information regarding the required Allocation of Rights Agreement.

f. **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 items such as innovative instrumentation and/or automatic test equipment.

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 doing so to be necessary.

COMPANY COMMERCIALIZATION REPORT (VOLUME 4)

Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD STTR 24.B BAA for full details on this requirement. Information contained in the CCR will not be considered by the Air Force during proposal evaluations.

SUPPORTING DOCUMENTS VOLUME (VOLUME 5)

The following documents may be required if applicable to your proposal:

1. 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/DD2345Ins tructions.aspx. DD Form 2345 approval will be required if proposal if selected for award.
2. Verification of Eligibility of Small Business Joint Ventures (Attachment 3 to the DOD STTR 24.B BAA)
3. Technical Data Rights Assertions (if asserting data rights restrictions)

FRAUD, WASTE, AND ABUSE TRAINING (VOLUME 6)

Note that 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.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)

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

AIR FORCE PROPOSAL EVALUATIONS

Proposals will be evaluated for overall merit in accordance with the criteria discussed in the 24.B BAA. DAF is seeking varying technical/scientific approaches and/or varying and new technologies that would be responsive to the problem statement(s) and area(s) of interest in the topic. Multiple procurements are planned and anticipated to be awarded as a result of the topic, each proposal is considered a separate procurement and will be evaluated on its own merit, and that the Government may award all, some, or none of the proposals. Any per-award or per-topic funding caps are budgetary estimates only, and more or less funding may become available. Funding decisions are made with complete disregard to the other awards under the same topic.

In accordance with Section 4 of the SBIR and STTR Extension Act of 2022, the DAF will review all proposals submitted in response to this BAA to assess security risks presented by small business concerns seeking a Federally funded award. The DAF will use information provided by the small business concern in response to the Disclosure of Foreign Affiliations or Relationships to Foreign Countries and the proposal to conduct a risk-based due diligence review on the cybersecurity practices, patent analysis, employee analysis, and foreign ownership of a small business concern, including the small business concern and employees of the small business concern to a foreign country, foreign person, foreign affiliation, or foreign entity. The DAF will also assess proposals utilizing open-source analysis and analytical tools, for the nondisclosures of the information set forth in 15 U.S.C. 638(g)(13). If DAF assesses that a small business concern has security risk(s), DAF will review the proposal, the evaluation, and the security risks and may decide not to select the proposal for award based upon a totality of the review.

MAJORITY OWNERSHIP IN PART BY MULTIPLE VENTURE CAPITAL, HEDGE FUND, AND PRIVATE EQUITY FIRMS

Small business concerns that are owned in majority part by multiple venture capital operating companies (VCOCs), hedge funds, or private equity funds are not eligible to submit applications or receive awards for Department of Air Force Topics.

PERFORMANCE OF WORK RE4QUIREMENTS AND LOCATION OF WORK

For both Phase I and Phase II, a minimum of 40% of each STTR award must be conducted by the awardee and a minimum of 30% of the effort must be performed by the single partnering Research Institution. Note, applicants and awardees may partner with multiple entities that separately meet the definition of a "Research Institution" as indicated in the SBIR BAA. Applicants may use only one partnering Research Institution to meet STTR eligibility requirements. The DAF will not consider requests for deviations to these performance of work requirements.

All R/R&D work must be performed in the United States. Based on a rare and unique circumstance, the DAF may approve a particular portion of the R/R&D work to be performed or obtained in a country outside of the United States. The awarding Funding Agreement officer must approve each specific condition in writing. Applicants seeking this approval must make such a request with their initial proposal submission. The DAF will not consider these requests prior to proposal submission.

DAF USE OF SUPPORT CONTRACTORS

Restrictive notices notwithstanding, proposals may be handled for administrative purposes only, by support contractors. These support contractors may include, but are not limited to TEC Solutions, Inc., APEX, Oasis Systems, Riverside Research, Peerless Technologies, HPC-COM, Mile Two, Montech, 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 CO Daniel J. Brewer (Daniel.Brewer.13@us.af.mil) with concerns regarding the use of support contractors.

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.

Automated feedback will be provided for Phase I proposals designated Not Selected. Additional feedback may be provided at the sole discretion of the DAF.

IMPORTANT: Proposals submitted to the DAF are received and evaluated by different organizations, handled 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.

The Air Force anticipates that all proposals will be evaluated and selections finalized within approximately 90 calendar days of solicitation close. Refrain from contacting the BAA CO for proposal status before that time.

Refer to the DoD STTR 24.B 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 J. Brewer, Daniel.Brewer.13@us.af.mil.

AIR FORCE SUBMISSION OF FINAL REPORTS

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

PHASE II PROPOSAL SUBMISSIONS

DAF organizations may request Phase II proposals while Phase I technical performance is ongoing or at any time after the conclusion of the period of performance. This decision will be based on the awardee's technical progress, as determined by an DAF Technical Point of Contact review using the Phase II review criteria outlined above.

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. Phase II dollar values, performance periods, and proposal content will be specified in the Phase II request for proposal.

NOTE: The DAF primarily makes STTR Phase I and II awards as Firm-Fixed-Price contracts. 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/STTR PROGRAM MANAGEMENT IMPROVEMENTS

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

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Department of Air Force STTR 24.B Topic Index

Topic Number	Topic Name	Maximum Value*	Maximum Duration**	Technical Volume Page Limit***
AF24B-T001	Flat Optic Micro Lenslet Array	$180,000.00	6	20
AF24B-T002	Neural Collapse for Responsible Artificial Intelligence in Directed Energy	$180,000.00	6	20
AF24B-T003	Quantum Algorithms for Military Cargo Transport	$180,000.00	6	20
SF24B-T004	Data-Centric AI in Multi Domain Awareness	$180,000.00	6	20
SF24B-T005	Multiple Hypothesis Management	$180,000.00	6	20
SF24B-T006	Probabilistic 3D Outer Zone Radiation Belt Model	$180,000.00	6	20
SF24B-T007	Finding Guaranteed RL Control for Satellite Systems	$180,000.00	6	20
SF24B-T008	Self-Regulating Heaters for Satellites	$180,000.00	6	20
SF24B-T009	Cultivating PWSA Innovations Through Collaboration	$180,000.00	6	20
AF24B-T010	GHz burst mode ultrashort pulse laser	$180,000.00	6	20
SF24B-T011	Into the Wild Transitioning Basic Rsh Algs to Ops	$180,000.00	6	20

*Proposals that exceed this amount will be disqualified.
**Proposals that exceed this duration will be disqualified.
***Pages/slides in excess of this count will not be considered during evaluations.

AF24B-T001 TITLE: Flat Optic Micro Lenslet Array

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Integrated Sensing and Cyber

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

OBJECTIVE: Develop a concept and demonstrate a flat optical system for use as a micro lenslet array, appropriate for use with digital micromirror (DMD) devices.

DESCRIPTION: Lenslet arrays provide optical functionality that is desirable for use with arrayed devices such as digital micromirror (DMD) devices, LED arrays, and laser arrays. Standard glass/plastic lenslet arrays have undesirable limitations including wavefront errors, acceptance angle, focal length, and device pitch. Flat replacements for traditional lenslet arrays are desired with pitch and formats that can match standard DMD formats, operate in the visible spectrum, have significant working distance, have large angular acceptance, are polarization agnostic, have high transmittance, have tunable designs, and are manufacturable at scale. An added advantage (optional) would be the ability to “tile” lenslet arrays to make a larger format device. Extension for use in mid-wave infrared (3.0µm to 5.0µm) is also of interest.

PHASE I: Concepts will be evaluated based on a variety of optical and geometrical characteristics such as: lens fill factor, minimum achievable focus spot for a lenslet, wavefront error/image quality, acceptance angle, working distance, bandwidth, uniformity across polarization states, and transmittance. Consideration is also provided for manufacturability, complexity, ability to “tile” arrays, and tunability to reach other bands as desired. The evaluations may be made using simulations if necessary, though preference is given to actual hardware feasibility demonstration using DMDs or representative hardware

PHASE II: Refinement of the concept, development of design, fabrication, and demonstration of a prototype and prototype experimentation/testing will constitute the majority of the Phase 2 effort. Any remaining concept refinements needed after a Phase 1 completion will be addressed early in the Phase 2 effort, ideally in parallel with the design efforts. Prototype to be developed should not be specific to a single illumination type (i.e. laser, LED, or halogen). The design process should include planning for demonstration and testing/measurements. Construction and demonstration of a prototype is expected to require a substantial portion of the phase 2 program depending on lead times of components requiring procurement as well as number of iterations of fabrication to refine the process. With proper planning for demonstration and testing, the final portion of the phase 2 program should be relatively short and produce high quality data that indicates the design functions as intended.

PHASE III DUAL USE APPLICATIONS: Outputs from Phase 2 are anticipated to be TRL 6 but may require additional effort to refine to a more manufacturable design. Phase 3 will concentrate on the manufacturability as well as the manufacturing process itself to prepare the vendor to commercially offer a fully operational product. A final product is expected to be demonstrated and marketed to AFRL as well as our transition partner in the 782d Test Squadron. Additional Phase 3 planning will occur during the

Phase 2 process once a design is established and manufacturing requirements and manufacturability become more apparent.

REFERENCES:

1. Fan, ZB., Qiu, HY., Zhang, HL. et al. A broadband achromatic metalens array for integral imaging in the visible. Light Sci Appl 8, 67 (2019).
2. Pisano, G., Austermann, J., Beall, J. et al. Development of Flat Silicon-Based Mesh Lens Arrays for Millimeter and Sub-millimeter Wave Astronomy. J Low Temp Phys 199, 923–934 (2020).;

KEYWORDS: lenslet; metamaterials; optical array; projection; hardware-in-the-loop; test; optics

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AF24B-T002 TITLE: Neural Collapse for Responsible Artificial Intelligence in Directed Energy

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Advanced Computing and Software; Directed Energy (DE)

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

OBJECTIVE: Purpose:
To develop theoretical foundations necessary to support and sustain Artificial Intelligence technologies within Directed Energy.

Motivation:
Modern neural network-based machine learning techniques achieve high performance, at the cost of limited explainability and understandability through their black box structure. As described in a recent Defense strategy [1] and directive [2] Defense Artificial Intelligence systems in general require a level of trust incompatible with state-of-the art machine learning systems. A recent executive order [3] further demonstrates the need for trustworthy Artificial Intelligence systems.

Benefit:
AFRL/RD is interested in investigating solutions that address the described black box incompatibility for Directed Energy-specific target acquisition and tracking problems. Specific problems might include acquisition of small, unmanned aircraft, cruise missiles, small ground-based targets, and anti-aircraft missiles. If successful, compatibility will have impact to both AFRL/RD and other Directed Energy organizations, with strong potential for generalization to other Department of Defense weapons and commercial applications such as medical diagnostic systems (e.g. the Food and Drug Administration's oncology diagnostics program [4].) The compatibility will enable trust and proliferation of predictive artificial intelligence-based decision-making systems, enabling the Warfighter to automate tasks and achieve well-understood behaviors.

Main Goal:
To understand neural network technology, beyond traditional black box models towards fully explainable, mathematically understood models, enabling Defense users to implement trusted artificial intelligence systems.
Subgoals:

1. (Basic Research) Study fundamentals of neural networks to enable deeper understanding in terms of neural network performance, performance bounds, and limitations, and achieve neural network explainability.
2. (Applied Research) Understand neural network fundamentals and their applicability to Directed Energy problems. Achieve compatibility with Defense strategies and directives [1] [2].

Deliverables:
Reports in Powerpoint and text-based manuscript formats.

A software package including material necessary to understand and reproduce SBIR results.

DESCRIPTION: Recent research has demonstrated a neural network training phenomenon, Double Descent [5]. Here, sufficiently large predictive classification networks can train beyond the overfitting regime and achieve lower local minimum test loss, approaching the global minimum. Later, it was shown that double descent-achieving networks can collapse, or converge, to a structure with well-defined mathematical properties [6]. This is called Neural Collapse, and its study has recently been an active research field regarding its implications on performance, optimality, robustness, and other traits.

AFRL/RD has interest in the Neural Collapse phenomenon because conclusions derived from its study may generalize across all neural networks achieving Neural Collapse. More specifically, recent research has investigated Neural Collapse for traits such as optimality [7], training success [8], transfer learning [9], and robustness [10]. While the state-of-the-art is not fully peer reviewed, success in these lines of research could lead to explainability and trust in a technology that has traditionally been considered a black box, achieving the objective of the STTR.

To meet the objective, potential tasks in several research directions are described below. These tasks are open ended, and comprehensive results are not expected before Phase III. Further related tasks in support of the goals may be proposed due to the fast-paced nature of the research area.

Applied Research (Export Controlled):

1. Demonstrate that networks trained on Directed Energy datasets such as CLIPS, in applications such target acquisition of small, unmanned aircraft, can achieve Double Descent and Neural Collapse.
2. Validation of recent research (References 7-10) with regards to correctness and applicability of Neural Collapse to the Directed Energy dataset.
3. Quantify generalizability of Neural Collapse across different Directed Energy application datasets and sensors. Understand Neural Collapse robustness to specific sensor, noise, and scenario types.

Information Theory/Optimality Basic Research (Not Export Controlled):

1. Using techniques such as Task Specific Information [11] to calculate quantitative optimal detector/classifier task performance, show that a Neural Collapsed network quantitatively approaches this performance value.
2. If such optimal performance is demonstrated, investigate implications derived from optimality including bounded network outputs and network robustness.
3. Quantify the degree of neural collapse in a network and relate this value as a function to quantified task performance.

Neural Collapse Behavior/Limitations Basic Research (Not Export Controlled):

1. Neural Collapse represents an end state; a neural network converges to the state but may never fully reach collapse. In addition, multiple layers in the network may reach an intermediate collapsed state [8, 12]. Define and justify what is quantitatively meant when a network should be declared to be in a collapsed state, and the implications in this declaration.
2. A network needs to be sufficiently large and have sufficient training to reach Neural Collapse. Quantify requirements that define when a network is capable of/qualified to reach a double descent/neural collapse state.
3. Quantify the resource costs and performance benefits associated with Neural Collapse. Are there performance benefits (Quantified with ROC/Precision and Recall/Confusion Matrix) associated with reaching Neural Collapse, and are there additional training/testing/inference/other costs associated with operating in a Neural Collapse state?

Results are expected through a software package, as well as in written form including reports and presentation, with likely submission to the DTIC database. Publication through conferences, articles, and press release is encouraged.

PHASE I: TECHNICAL OBJECTIVES:

1) Downselect imaging datasets for training a neural network-based detection system, including Defense/Directed Energy datasets and public, popular datasets. Successfully demonstrate Neural Collapse behavior on Directed Energy target datasets to demonstrate application, as well as popular public datasets, through network training and transfer learning.
2) Identify promising Neural Collapse research tasks for Phase II and conduct preliminary research demonstrating potential value in this tasking.

TECHNICAL OUTCOMES:

1) Neural collapse is confirmed as a phenomenon affecting neural networks and confirmed as relevant to Directed Energy applications.
2) Delivery of a software package demonstrating existence of the Neural Collapse phenomenon. The package should contain source code, build scripts and instructions, a software dependency list including acquisition and installation instructions, dataset acquisition instructions, and software documentation including structural and functional descriptions.

PROGRAM OUTCOMES:

1) Establish plans including statement of work, work breakdown, and software development documents for specific tasks to complete in Phase II, either from the Project Description, or self-developed.
2) Establish relationships and collaborations with interested Directed Energy and Defense partners

PHASE II: TECHNICAL OBJECTIVES:

1) Complete, demonstrate, and report on basic and applied research efforts to further project goals.

TECHNICAL OUTCOMES:

1) Basic Research: Inform the Applied Research effort and report on and publish results from task completion.
2) Applied Research: Demonstrate that Neural Collapse
3) Delivery of software package demonstrating the specifically researched Neural Collapse phenomenon. The package should contain source code, build scripts and instructions, a software dependency list including acquisition and installation instructions, dataset acquisition instructions, and software documentation including structural and functional descriptions.

PROGRAM OUTCOMES:

1) Demonstrate that Neural Collapse may have a significant impact on Directed Energy applications as well as broader detection/classification applications.

PHASE III DUAL USE APPLICATIONS:

ENTRY CRITERIA: TRL-3 or TRL-4

TECHNICAL OBJECTIVES:

1) Conduct statistical analysis using effort-specific data recordings from either a Directed Energy testbed such as BC TRAIL or a laboratory setup, demonstrating discovered Neural Collapse implications as applied to Directed Energy systems. These implications might include robustness, optimality or transferability, as discussed in the Project Description.

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TECHNICAL OUTCOMES:

2) 1)Demonstration of Neural Collapse and its implications as a TRL-5 capability. If successful, this demonstration will enable integration with DE imaging systems and AI subsystems.

PROGRAM OUTCOMES:

1) Successful Integration of Neural Collapse concepts into DE AI system development, enabling compliance with orders, strategies, and regulations mandating trustworthy AI.

REFERENCES:

1. DoD Responsible AI Working Council, “DoD Responsible Artificial Intelligence Strategy and Implementation Pathway,” June 21, 2022
2. DoD Directive 3000.09, “Autonomy in Weapons Systems”, January 25, 2023
3. Biden, Joseph R. "Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence." (2023)
4. https://www.fda.gov/about-fda/oncology-center-excellence/oncology-therapeutic-and-diagnostic-devices;
5. Belkin, Mikhail, et al. "Reconciling modern machine-learning practice and the classical bias–variance trade-off." Proceedings of the National Academy of Sciences 116.32 (2019): 15849-15854.;
6. Papyan, Vardan, X. Y. Han, and David L. Donoho. "Prevalence of neural collapse during the terminal phase of deep learning training." Proceedings of the National Academy of Sciences 117.40 (2020): 24652-24663.;
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KEYWORDS: Machine Learning; Artificial Intelligence; Applied Mathematics; System Performance; Directed Energy; Computer Vision; Image Processing

VERSION 3

AF24B-T003 TITLE: Quantum Algorithms for Military Cargo Transport

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Quantum Science; Sustainment & Logistics; Advanced Computing and Software

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

OBJECTIVE: The objective of this topic is to develop and document quantum algorithms and quantum computer specifications for solving military cargo transport, as scaled from regional through full global coverage, on increasing forecast durations, while accommodating disruptions consistent with wartime operations.

DESCRIPTION: Military cargo transport and commercial package delivery are problems with similar structure and complexity. An example solution for the transport problem is a set of assignments within a particular forecast timeframe, such that each assignment associates payload, support materials (e.g., fuel), and aircrew with an aircraft, which is in turn assigned a particular route and destination. As the solution timeframe lengthens, so too increases the number of assignments associated with any specific aircraft. Any disruptions to the assignments, whether due to natural or man-made influences, incur a significant computational burden potentially accompanied by an operational halt.

Candidate transport assignments are generated from a combinatorial explosion of factors and quantities, and each candidate assignment must be validated for consistency and compatibility with constraints such as aircraft maintenance schedules, aircrew weekly hours, fuel availability, refueling duration, route availability, expected load/unload duration, and available hangar and/or ramp space. Any candidate solution requires its constituent assignments to be further checked against one another to prevent redundancy and mutual exclusivity. Full solution optimization via classical computing appears to be intractable (possibly NP-complete), requiring far more processing time than practical real-world operations allow.

Commercially available transport planning systems sacrifice optimality in favor of actionable solutions on relevant decision timelines. These systems – which reduce but do not escape the underlying computationally intensive resource allocation – achieve their goals by carefully restructuring the problem for example with additional constraints (e.g., shorter forecast duration, reduced geographic coverage) or through efficient heuristics (e.g., data-driven predictive assignment models).

Processing power is a continual critical enabler for practical planning systems. Quantum computing shows promise for resource allocation problems and with the right quantum algorithm(s) could even make optimal solutions achievable on operationally relevant timelines. However, the nature of the cargo transport planning problem may be such that some or all sub-problems are best solved with classical computing techniques. Critical investigations within this activity include 1) the military cargo transport problem and how its overall complexity is influenced by the scale of key factors (e.g., number of aircraft, time horizon, number of sites), 2) which elements of the overall military cargo transport problem and what quantum algorithm(s) are most likely to exhibit quantum advantage, 3) what real-world measurements and user inputs must be accommodated by a quantum algorithm for military cargo transport, 4) at what scale quantum advantage is likely to be achieved for military cargo transport as a whole and/or for key sub-problems within a hybrid quantum-classical solution, and 5) how the choice of quantum computing architecture influences the quantum system specifications required to execute the quantum algorithm(s) solving military cargo transport.

PHASE I: Awardee(s) will analyze the military transport resource allocation problem, identifying and documenting key factors and scalability impacts influencing complexity. Awardee(s) will develop quantum algorithms or a hybrid set of classical and quantum algorithms providing optimal solutions -- or improved approximations to the optimal solution -- to military cargo transport at all scales and timelines of military interest; developed algorithms must provide computational advantage over the currently fielded state of the art. Awardee(s) will recommend specifications for one or more quantum computing architectures capable of executing the developed quantum algorithms for military cargo transport at operationally relevant scales.

PHASE II: Awardee(s) will prototype or develop approaches to prototype the recommended quantum or hybrid quantum-classical system. Awardee(s) will develop practical approaches to assess system utility and assess quantum advantage at multiple operationally relevant problem scales. Awardee(s) will execute the developed assessments as state of the art permits.

PHASE III DUAL USE APPLICATIONS: Awardee(s) can expect to develop a strategy for transitioning the technology, with appropriate consideration for critical technology thresholds and scale at which quantum advantage applies.

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2. * 2. *A. M. Dalzell et al, "Quantum algorithms: A survey of applications and end-to-end complexities", arXiv, 2023. https://arxiv.org/abs/2310.03011;
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KEYWORDS: quantum algorithms; quantum computing; logistics; military transport

SF24B-T004 TITLE: Data-Centric AI in Multi Domain Awareness

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

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

OBJECTIVE: The objectives of this topic are a) to develop, test, and demonstrate a data-centric AI solution for processing Multi Domain Awareness data and b) identify and illustrate the potential negative effects of insufficient training data in automated processing of multi-domain data streams.

DESCRIPTION: Enhanced situational awareness and flight safety support in the space domain within and beyond geosynchronous orbit (GEO) is achievable given sufficient data strategies. Observational evidence of spacecraft anomalies is manifested in multiple data types to include raw EO/IR imagery features, astrometric and photometric features, and features associated with their radio-frequency/RF payload. When this data is collected in great volume, from multiple modalities, and geographic locations, there is significant opportunity to enable reliable automated alerting. Today defining normal operations in space so that abnormal behavior can be flagged and more deeply observed is an area of research which addresses fundamental developments required to begin to define a baseline for real-time automated alerting for increasingly crowded orbit neighborhoods, as well as inform how this baseline may be extended to support missions in orbits beyond GEO. This is a significant need as new activities in cislunar space are planned for the coming years. This topic seeks to:

1) Define data-driven methods to drive the development and testing of an ontology of automated alerts in support of government and commercial applications and
2) Develop foundational mathematical solutions needed to enable these mappings on multiple timescales and to properly quantify the uncertainty in these mappings to effectively support decision making.

This includes mapping high frequency and geometrically diverse collection data to:

a) Specify/classify maneuver alerts as station-keeping or not,
b) Specify observed anomaly types and classify them on the basis of astrometric, photometric and RF features observed, and
c) c.) Quantify confidence/uncertainty in the mapping from input data to selected alerts.

To develop an explainable alert ontology, the awardee(s) will develop a supervised learning approach which combines feedback from experts in space domain awareness with Generative Adversarial Networks (GANs) and Convolutional Neural Networks (CNNs). The awardee(s) will show the regrets associated with insufficient training of SDA models and compare the assessed results of their solution at different levels and qualities of training using available SDA data. Importantly the awardee(s) will identify various forms of "data cascades" which can occur when insufficient data work is performed in the development of automated processing routines applied to the interpretation of SDA data. When do leaks and false alarms manifest into undesired downstream effects?

PHASE I: Awardee(s) will conceive of, develop, and demonstrate multiple methods for automated processing of SDA data which result in meaningful conclusions regarding the observed operations of spacecraft. Awardee(s) will exercise these algorithms using available SDA data. GFE will not be provided.

PHASE II: Awardee(s) will extend these methods to fuse multiple modalities and evaluate when and where errant conclusions can be made and what the underlying data conditions are that lead to these non-ideal conclusions.

PHASE III DUAL USE APPLICATIONS: Awardee(s) will develop a strategy to transition prototype residual capabilities and incremental proliferation based on operational requirements.

REFERENCES:

4. Press, G. (2021, June 16). Andrew Ng launches a campaign for data-centric AI. Forbes. https://www.forbes.com/sites/gilpress/2021/06/16/andrew-ng-launches-a-campaign-for-data-centric-ai/?sh=2f32fc6674f5
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KEYWORDS: machine learning; artificial intelligence; data fusion; space domain awareness;

VERSION 3

SF24B-T005 TITLE: Multiple Hypothesis Management

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy

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

OBJECTIVE: Develop methodology and prototype software to enable autonomous hypothesis management and resolution of potential courses of action based on available data.

DESCRIPTION: As technology advances, services and capabilities become computerized, and an increasing number of processes are conducted electronically, there as an increasing need for real-time decision-making systems with many capabilities in various decision spaces. With intelligence gathering rapidly growing in size and sensors producing increasing amounts of data, manual inspection of the data quickly becomes infeasible. A common mantra in information fusion is that "analysts are drowning in data but starving for information," and this is readily apparent across several domains. The focus of this effort will be to develop a method to manage large decision spaces where several hypotheses must be considered and analyzed both spatially and temporally. Owing to the decision space of different types of situational awareness, such decision support systems must concentrate on and nominate specific decision tracks or rank multiple tracks representing the hypothesis. A commander's options during a mission span a large decision space, requiring understanding possible courses of action (COAs) for both red and blue forces and domain and problem complexities.

A scalable method is sought to assist decision makers through various analysis and modeling techniques that automate the evaluation of options to take at any given state while presenting the best alternatives clearly and concisely. A key aspect is to manage a decision space that could grow exponentially, while maintaining the most plausible and impactful COAs over the life of the mission.

PHASE I: Develop methodology for hypothesis management. Conduct analysis of alternatives and develop architecture for proposed solution. Develop use case in one or more domains and identify available and required data to support hypothesis management. GFE will not be provided.

PHASE II: Develop prototype software solution that implements chosen methodology for chosen use case. Integrate available data types and sources and output metrics that rank or score the likelihood of each plausible hypothesis. Test performance using real-world data. GFE will not be provided.

PHASE III DUAL USE APPLICATIONS: The Phase III effort may include implementation of the prototype software in operational environments for assessment by analysts against real-world, real-time data. Solution performance may be evaluated against the current state of the art. Military uses include enemy course of action determination across multiple domains. Expected TRL at Phase III entry is 5.

REFERENCES:

1. Haberlin, Richard, da Costa, Paulo, Laskey, Kathryn, "Hypothesis Management in Support of Inferential Reasoning", Fifteenth International Command and Control Research and Technology Symposium, May, 2010. https://apps.dtic.mil/sti/citations/ADA525233;

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2. Gordon, J., Shortliffe, E.H. (2008). A Method for Managing Evidential Reasoning in a Hierarchical Hypothesis Space. In: Yager, R.R., Liu, L. (eds) Classic Works of the Dempster-Shafer Theory of Belief Functions. Studies in Fuzziness and Soft Computing, vol 219. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-44792-4_12;

KEYWORDS: hypothesis management; hypothesis resolution; courses of action; domain awareness; situational awareness

VERSION 3

SF24B-T006 TITLE: Probabilistic 3D Outer Zone Radiation Belt Model

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Space Technology

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

OBJECTIVE: The objective of this topic is to create an accurate predictive 3 dimensional radiation belt model which can support a capability that can provide an actionable forecast for "All Clear" or give the likelihood of an internal charging hazard. This will require forecasts of flux levels at a range of energies from as low as 500 keV to >2MeV electrons. The forecasts should be for up to 7 days, with probabilities and confidence levels. While the confidence levels at higher that 2 or 3 days out will likely be small given the current level of science, this will give us a base to work from for future improvements.

DESCRIPTION: The outer-zone radiation belts are a highly variable and dynamic population of very energetic electrons that exist between about 10,000 km and 40,000 km above the Earth's surface at the equator, but penetrate to Low Earth Orbit at high latitudes. They can penetrate satellite surfaces and deposit their charge into or near the interior electronics, which can lead to damaging discharges. With the recent National Defense Strategy's emphasis on resilient satellites, it is important to develop specification and forecast capabilities that can provide good estimates of the current and near future radiation belt threat levels to allow decision makers the best knowledge of the environment when planning upcoming operations. A knowledge of the environment also allows satellite operators the ability to quickly determine the probability of space environment contributions to anomalies, and more readily ascertain the possibility of pacing competitor "gray zone" activities that could lead to satellite malfunctions.

Current operational specification and forecast models such as the Spacecraft Environmental Anomalies Expert System – Real time (SEAESRT) and the Relativistic Electron Forecast Model used by the National Oceanic and Atmospheric Administration/Space Weather Prediction Center (NOAA/SWPC) only address geosynchronous orbit. Current science addresses the full outer-zone electron radiation belts, and should be able to significantly improve upon the existing capability. Some example 3D radiation belt models are the AFRL model [1], Dynamic Radiation Environment Assimilation Model (DREAM) [2], the British Antarctic Survey Radiation Belt Model [3] and others. For forecasting there are current efforts from simple approaches such as The Satellite Risk Prediction and Radiation Forecast System (SaRIF), to sophisticated efforts like SafeSpace model [5].

This is a call for new capabilities that can specify and forecast the energetic electron fluxes in the outer-zone for up to 7 days. These nowcasts and forecasts should include the probabilities of different flux levels at locations within the region and the confidence level of each probability. These fluxes will be used to drive a hazard specification capability.

PHASE I: Demonstrate a capability that can accurately specify hazardous radiation belt fluxes for energies in the range from 0.75 to 6 MeV and >2MeV using operational data.

1. The fluxes must be specified throughout the outer radiation belt zone using accuracy and bias metrics which will be provided and for periods of time which will be specified.

2. There will also be a demonstration that the capability can make accurate 24 and 48 hour forecasts of the same fluxes throughout the radiation belts with acceptable probabilities and confidence levels, using the provided metrics.

AFRL will specify the observations to be used for the truth data.

PHASE II: Phase II will have X objectives:

1. Demonstrate that the performance in Phase I can be obtained with a real-time model that only uses operational data.
2. The specification will be demonstrated for a more significant time period, as will the original forecast.
3. The forecast with probabilities and confidence levels will be extended to 7 days, we will look for a reasonable fall-off in accuracy with time.
4. The capability will be compared with a model being developed by a partner.

AFRL will specify the observations to be used for the truth data.
If the results are satisfactory, we will recommend this model to our customers, who will be following the effort, for a phase III transition.

PHASE III DUAL USE APPLICATIONS: The phased III will have as objectives:

1. Further validation of the model to provide our customer with a more complete understanding of the model's strengths and weaknesses.
2. Where time and resources permit, there may be further upgrades to the model based on the previous validation results.
3. The main effort in phase III will be to produce an Algorithm Theoretical Basis Document and provide support to the team transitioning the capability to operations.

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2. Reeves, G. D., Chen, Y., Cunningham, G. S., Friedel, R. W. H., Henderson, M. G., Jordanova, V. K., Koller, J., Morley, S. K., Thomsen, M. F., and Zaharia, S. (2012), Dynamic Radiation Environment Assimilation Model: DREAM, Space Weather, 10, S03006, doi:10.1029/2011SW000729.
3. Glauert, S. A., Horne, R. B., and Meredith, N. P. (2014), Three-dimensional electron radiation belt simulations using the BAS Radiation Belt Model with new diffusion models for chorus, plasmaspheric hiss, and lightning-generated whistlers, J. Geophys. Res. Space Physics, 119, 268–289, doi:10.1002/2013JA019281.
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KEYWORDS: Radiation Belts; Outer-Zone; Forecast; Prediction

VERSION 3

SF24B-T007 TITLE: Finding Guaranteed RL Control for Satellite Systems

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Trusted AI and Autonomy; Space Technology

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

OBJECTIVE: The focus of this topic is to discover and design machine learning or reinforcement learning architectures for use within a satellite control context which are capable of providing guaranteed closed-loop behavior in a nonlinear controls context.

DESCRIPTION: Machine or reinforcement learning techniques have proven their usefulness in creating control schemes that can handle complicated inputs and maneuver vehicles as intended. One of the fundamental drawbacks of these controllers is how quickly their capabilities have grown in comparison to the theoretical guarantees normally required to ensure their safety. At the moment, machine learning-based controllers are rapidly being adopted despite the lack of guaranteed safety. The future of satellite autonomy may involve these types of controllers, but these controllers must be shown to be safe for flight with guaranteed closed-loop behavior if they are to be implemented in space. This topic aims to discover whether certain control structures, activation functions, and training results for machine/reinforcement learning controllers exist that can provide formal guarantees for a satellite's behavior and, if so, what they may be.

PHASE I: Awardee(s) will conduct a comprehensive review of current research in machine/reinforcement learning techniques and architectures capable of providing performance guarantees within a control context. Awardee(s) will investigate and compile the possible requirements for a satellite controller as well as the necessary theorems needed to demonstrate guaranteed behavior. Awardee(s) will devise a test plan capable of demonstrating the use of the control systems using machine/reinforcement learning techniques and allowing the comparison of them between theory and practice.

PHASE II: Awardee(s) will design the theorems and control structures that illustrate what type of machine learning-based models and training approaches can be shown to provide provable stability guarantees under certain conditions. Implement these control systems on multiple vehicles, including a representative satellite, showcasing the adherence of these controllers to their theoretical guarantees.

PHASE III DUAL USE APPLICATIONS: In cooperative efforts with one or more satellite software manufacturers and military satellite system developers, awardee(s) should expect to integrate the proposed control algorithms with satellite software. Awardee(s) should expect to demonstrate the control system performance with it running on board a satellite. Awardee(s) should expect to evaluate transition opportunities for utilization in approved Government civilian applications.

REFERENCES:

1. RL uncertainty characterization still relies on statistical estimation: Clements, William R., et al. "Estimating risk and uncertainty in deep reinforcement learning." arXiv preprint arXiv:1905.09638 (2019);

2. Trained RL agents still suffer from brittleness and data issues: Lockwood, Owen, and Mei Si. "A Review of Uncertainty for Deep Reinforcement Learning." Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment. Vol. 18. No. 1. 2022;
3. State of the art guarantees still exist at most only for linear models: Z. Marvi and B. Kiumarsi, "Reinforcement Learning With Safety and Stability Guarantees During Exploration For Linear Systems," in IEEE Open Journal of Control Systems, vol. 1, pp. 322-334, 2022, doi: 10.1109/OJCSYS.2022.3209945.;

KEYWORDS: Reinforcement learning; nonlinear controls; optimization; satellite control; autonomy

SF24B-T008 TITLE: Self-Regulating Heaters for Satellites

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Space Technology

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

OBJECTIVE: The objective of this topic is to develop and commercialize self-regulating (positive temperature coefficient, PTC) heaters for use on
satellites in any earth orbit.

DESCRIPTION: Self-regulating heaters are heaters with a designed-in temperature setpoint that exists as a property of the resistor material. They are 'smart' heaters, automatically and independently warming each region of the heater circuit to the designed setpoint without a temperature sensor. The electrical resistance of the heater material jumps substantially at the setpoint, inhibiting electric flow and production of heat above the setpoint temperature. Self-regulating heaters are in use in the petrochemical and automotive industries for pipe freeze protection and seat warmers. The space industry needs self-regulating heaters for propellant system heaters where allowable temperature ranges are tight and thermal environments vary in both time and space. Conventional solutions to propellant system thermal control are resource intensive, requiring much engineering design and touch labor as well as much hardware and burdening the flight computer to control the circuits. Self-regulating heaters reduce all of these resource demands. Self-regulating heaters can also provide similar benefits for other satellite heaters such as those for batteries, mechanisms, and antennas.

Existing self-regulating heaters are not suited for space applications for several reasons:

1) the form factor is too large and inflexible: existing self-regulating heaters are a stiff cable while satellite self-regulating heaters must be a thin-film heater such as adhesively-applied polyimide heaters commonly used on satellites. Additionally, these heaters must be suitable to install on two orthogonal bend axes: a 1/8" bend radius and a 3" bend radius,
2) existing self-regulating heaters provide their resistance transition via a melt expansion process to break the percolating path; this means that existing self-regulating heaters cannot be exposed to temperatures greater than their setpoint temperature,
3) Existing self-regulating heaters are not designed to handle the space environment; specifically: vacuum, ionizing radiation, and wide thermal cycles.

This topic solicits proposals to develop and commercialize self-regulating heaters for space applications that address these aforementioned insufficiencies of existing self-regulating heaters. Additionally, the materials design must be capable of tuning during manufacturing of the material for setpoint temperatures between -5 and 20 C. A 30:1 (threshold) and 100:1 (objective) turndown ratio between the electrical resistances above and below the setpoint temperature must be achieved. The technology must be capable of yielding designs operating with any voltage between 12 and 100 VDC, and must be capable of producing designs yielding 1 to 10 W/in2 heat flux at the fully ON condition. Capable to withstand exposure to environments in all of the following orbits: 5 years in low earth orbit (LEO), 10 years in middle earth orbit (MEO), or 15 years in geosynchronous earth orbit (GEO) including vacuum, ionizing radiation, and thermal cycling. Radiation environments should assume the technology receives 40 mils of spacecraft Aluminum shielding (threshold) or no additional shielding (objective); radiation shields incorporated in the heater will be considered but radiation-hardened heater materials are strongly preferred. Thermal cycles between -5 and 40 C, with LEO 60k cycles, MEO 15k cycles, and GEO 6k cycles. Also survive up to 10 thermal cycles from -40 to 70 C. The material should always remain a solid. The manufacturing process should be scalable, e.g. screen printing techniques; the installation process should minimize touch labor. Proposers must demonstrate a strong intent and capability to commercialize the technology. Proposers are strongly encouraged to form teams with manufacturing partners and systems integrators for technology transition.

PHASE I: Awardee(s) will demonstrate by modeling and analysis and/or test the feasibility of the concept to meet all requirements. Develop and test the performance of prototype hardware.

PHASE II: Awardee(s) will further develop the prototype to increase performance, manufacturability and scalability of the hardware. Awardee(s) will test environmental capability of the hardware. The culmination of the Phase II effort shall include the hardware delivery of 10 functional, tested self-regulating heaters demonstrating a variety of sizes and mounting configurations.

PHASE III DUAL USE APPLICATIONS: Awardee(s) can expect to develop, produce, and bring to market a fully flight qualified self-regulating heater product line; transition the technology to at least one satellite integrator.

REFERENCES:

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2. Arco Engineering. Chromalox Electrical Heat Tracing Systems Design Guide. Retrieved from Arco Engineering;
3. Chen, Zheng, et al. "Fast and reversible thermoresponsive polymer switching materials for safer batteries." Nature Energy 1.1 (2016): 15009;
4. Dudon, Jean-Paul, et al. "Flexible Self-Regulating heater (FSRH) using PTC effect: A promising technology for future spacecraft thermal control." 46th International Conference on Environmental Systems, 2016. KEYWORDS: Thermal Control, Thermal Management, Satellites, Heaters, Self-Regulating Heaters CONTACT(S): Jon Allison AFRL/RVSV 5058533080 jonathan.allison.1@spaceforce.mil;

KEYWORDS: Thermal Control, Thermal Management, Satellites, Heaters, Self-Regulating Heaters

VERSION 3

SF24B-T009 TITLE: Cultivating PWSA Innovations Through Collaboration

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Space Technology

OBJECTIVE: Provide novel and innovative new technology to bolster the United States Space Force (USSF) Space Development Agency's (SDA) advancement of the Proliferated Warfighter Space Architecture (PWSA). SDA seeks proposals encompassing novel mission, system, value and warfighting engineering concepts, technologies, and capabilities which facilitate leap-ahead improvements for planned PWSA segments, layers and tranches or enable the creation of new missions and capabilities to address emerging warfighter needs. This effort aligns with the imperative to fortify space capabilities, ensuring their resilience against potential attacks, and to counter adversaries' advancements in space-based military capabilities targeting terrestrial assets, especially high-value power projection assets.

DESCRIPTION: SDA is actively seeking innovative proposals to advance the PWSA and create additional capability for the warfighter while maintaining affordability and resilience across the architecture. This call encompasses a wide array of themes, ranging from integrating commercially-sensed data into the transport layer by advancing SDA-standard compatible Optical Inter-Satellite Link (OISL) technologies, to networking, in-space processing, power enhancement for commoditized spacecraft buses, and robust multi-level security and cross domain solutions. These themes aim to drive advancements in affordability, capability, viability and interoperability. The goal is to bolster the resilience and capabilities of space assets while enabling new layers of capabilities to address evolving warfighter needs in a dynamic and challenging space environment.

PHASE I: The focus of Phase I is to identify and demonstrate the feasibility of novel technologies aimed at bolstering the PWSA via a collaborative feasibility study in partnership with a Research Institution (RI). Leveraging the collective expertise of the research institution and the proposing small business, the emphasis should be on using analytical or computational methods to move beyond first principles and document proposed advancements, culminating in a demonstrative product that establishes the approach's viability and enables Phase II planning. While a complete production-level simulation may not be necessary, the computational intensity of the effort necessitates an unequivocal demonstration of the proposed methods, even if access to supercomputing resources is limited. This phase's goal is to affirm the potential and practicality of the outlined technological approaches, validating their computational foundations to efficiently create new warfighting capabilities enabled by a set of interoperable resilient, global, proliferated low Earth orbit spaceborne constellations. The successful collaboration between SDA, a small business, and an RI should contribute to widespread applications within the space enterprise, offering enhanced security and resilience for space-based architectures, and potentially extending benefits to broader national security interests.

PHASE II: Phase II builds upon the validated feasibility from Phase I by transitioning toward technology maturation and integration within operational contexts. Leveraging the established collaborative partnership between the Space Development Agency (SDA), a small business, and a Research Institution (RI), Phase II focuses on refining and advancing the demonstrated technological approaches. This phase emphasizes rigorous testing and validation, aiming to develop a prototype or functioning model that substantiates the viability of the proposed methods in practical settings. The emphasis remains on computational validation and real-world applicability, ensuring the technology's readiness for integration into Space Force systems. Alongside technical advancements, Phase II targets engagement with specialized government transition programs like Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Transition (STP) or Rapid Innovation Fund (RIF) to facilitate the technology's integration into operational environments. This phase aims for a seamless transition from research and development to operational readiness, ultimately contributing to enhanced security and resilience for space-based architectures, aligning with broader national security imperatives.

PHASE III DUAL USE APPLICATIONS: In Phase III, the focus remains on refining the technology developed within Space Force operational environments. Funded through non-SBIR/STTR sources, this phase builds upon validated prototypes and successful Phase II outcomes. The emphasis lies in advancing the technology for operational readiness via comprehensive testing, validation, and operational assessments. Leveraging established partnerships, Phase III is dedicated to transitioning the technology into established Space Force programs or operational systems. While SBIR/STTR applications may not fund this phase, engagement with government transition programs like the Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Transition (STP) or Rapid Innovation Fund (RIF) remains crucial for securing necessary resources and funding to seamlessly integrate the technology into existing defense programs. Ultimately, Phase III aims for the successful deployment of this technology to bolster the security, resilience, and operational capabilities of space-based architectures, aligning with broader national security objectives and the Space Force's mission imperatives.

REFERENCES:

1. https://www.sda.mil/home/work-with-us/resources/;

KEYWORDS: Cryptography; Networking; Resilience; Interoperability; Affordability; Mission; Warfighting

AF24B-T010 TITLE: GHz burst mode ultrashort pulse laser

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Directed Energy (DE)

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

OBJECTIVE: The Air Force seeks the development of robust, compact, extreme repetition rate, high per pulse energy ultrashort pulse lasers with pulse on demand capability. Specifically, we seek advancements towards developing a turn-key GHz or higher repetition rate in a burst mode system. Ideally this system has a tunable rep-rate. It is desirable to have two operational modes: one that is externally trigger-able to sub-millisecond timing that yields a series of a few bursts and another that allows the system to continuously fire bursts at 1 Hz or better for up to several seconds. The resulting system at minimum should be compact or clearly scalable to compact package and be maintainable by non-specialists or minimal maintenance from laser experts.

DESCRIPTION: The Air Force Research Laboratory seeks to find novel ways to counter rf and EO/IR sensors and effectively ablate materials. The Air Force is seeking innovations towards developing burst mode lasers with tunable pulse trains of 1-20 GHz rep rate with individual pulses on the order of 100 mJ, pulse durations on the order of 1 ps, and bursts of 10 pulses or better. The Air Force seeks development of a system that operates in two modes: externally triggerable 'on-demand' burst mode with sub-millisecond trigger delay, and a continuous mode that allows for burst to occur at 1 Hz or better for several seconds. This system would allow the Air Force to further explore the feasibility of adopting such technology for military utility. A successful project will document, design, and test a laser system that meets these specifications. Such a solution may include commercial-off-the-shelf components, however will require novel laser engineering to achieve the desired burst pulse characteristics. A successful system should be compact and require minimal maintenance. Basic day to day operation should be achievable by a non-expert, e.g. turn on and shut down of system does not require a laser engineer to realign system frequently, changing frequencies should not require manual moving of optical components. If proposers find that the requirements in all parameters are infeasible, they should propose to what they believe can be achieved and evaluations will be scored accordingly. Intra-burst rep rate tunability and pulse-on-demand are the highest air force priorities for this effort, although the high frequency rep rate target values should be as-achievable. Pulse duration, number of pulses per burst, inter-pulse rep rate, and energy requirements are more flexible, but should be sufficient to demonstrate desired nonlinear laser-plasma interactions for air force applications. In addition to demonstration of laser technology goals, calibrated measurement of tunable rf resulting from the laser plasma, burn through rates on selected samples, and characterized supercontinuum in selected samples will be considered major milestones for the final product.

PHASE I: Phase I will consist of designing, costing, and specifying components needed for the planned system. Periodic updates will be required to ensure team is on track to meeting project objectives. System design should be supported by modeling and engineering calculations to support the design feasibility. Model should provide clear performance goals for the final laser specifications (ie pulse profiles, wavelength, energy, trigger modes) that the system should aim to meet in Phase II. Applicants should provide proof of concept/breadboard demonstration for novel and/or high risk concepts key to phase II success. Applicants should detail a statement of work with timelines of system development and personnel required for its successful completion.

PHASE II: Phase II should continue to build off the foundation laid in Phase I. Awardee(s) should execute design proposed in Phase I and benchmark system's capabilities. During this time applicants should continue to iterate and improve on design to better meet the goal of tunable GHz burst mode laser with ~100 mJ, and ~ps individual pulses. The end of Phase II should result in a prototype that meets the goals of this project that is compact, or with clear paths to being compact, and operable by non-experts. An ideal final system will not require manual movement of optical components by personnel to change the laser operation. In addition to demonstration of a laser system that meets goals of the project, calibrated measurement of tunable rf resulting from the laser plasma, burn through rates on selected samples, and characterized supercontinuum in selected samples will be considered major milestones.

PHASE III DUAL USE APPLICATIONS: If laser-material interaction milestones of phase II are sufficiently promising, the air force will seek phase III funds to further develop and acquire a laser system that is compact, ruggedized, and commercially available and which meets thresholds requested by the topic. We anticipate TRL 3 at entry of Phase III. Depending on magnitude of RF demonstration milestone in phase II, DAF demonstration follow-on funding may be sought to support phase III development and transition to TRL 6.

REFERENCES:
1. G. Blair, P. Sprangle. "Generation of rf radiation by low-intensity laser pulse trains in air," in Phys. Rev. E, vol. 108, pp. 015203, 2023.;
2. Danielle Reyes, Haley Kerrigan, Jessica Peña, Nathan Bodnar, Robert Bernath, Martin Richardson, and Shermineh Rostami Fairchild, "Temporal stitching in burst-mode filamentation," J. Opt. Soc. Am. B 36, G52-G56 (2019);

KEYWORDS: burst mode laser; ultrashort pulse; high repetition rate; pulsed laser; high average power

SF24B-T011 TITLE: Into the Wild-Transitioning Basic Rsh Algs to Ops

OUSD (R&E) CRITICAL TECHNOLOGY AREA(S): Space Technology

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

OBJECTIVE: Transition basic research algorithms developed previously with AFOSR 6.1 dollars into operations. These algorithms were developed to improve space domain awareness (SDA) to monitor the satellites in earth orbits. AFOSR is working with the Space Systems Command (SSC) TAP lab and with the Space Operations Command (SpOC) to transition and test these algorithms.

DESCRIPTION: AFOSR under collaboration with USSF Delta Operators identified several research algorithms that have the potential to improve space domain awareness (SDA) for USSF operational community. These algorithms were developed by academic researchers at many universities, tested on various platforms using many different data sources. These algorithms are in the area of orbit prediction and uncertainty quantification, change detection, characterization, tracking, and tasking. This effort will take those algorithms and mature them to perform on a single platform and test/evaluate the algorithms on relevant operational data. Algorithms that show promise to improve SDA for USSF will be matured further for potential transition to operations. A support letter from USSF is available upon request from AFWERX. Reference papers for some of the subject algorithms are shown in the reference cell. AFOSR is working collaboratively with SSC and SpOC on this effort. We have transition paths already identified. AFOSR only has 6.1 funds and cannot mature these algorithms. The SBIR program is perfect to provide the maturation of these algorithms for transition to operations.

PHASE I: Phase I will test the previously developed algorithms on operational data in collaboration with the SSC TAP lab. Testing results will be used to identify algorithms maturity and individual algorithm transition plan. Testing will also be used to mature and improve algorithm performance. A common platform where the algorithms will be integrated into in phase I will be identified, such as AFSIM, and a plan developed for how the algorithms will be integrated into the platform and how it will pull data. A common data format will be identified. Phase I output will be testing data, identification of a common platform to access data and run the algorithm, and a plan for algorithm integration.

PHASE II: Phase II will be a software effort to put all subject algorithms onto a single platform (such as AFSIM), tested with relevant data provided by USSF, conduct wargaming scenarios to evaluate the algorithms, identify strengths and weaknesses of subject algorithms. The results of Phase II will be used to identify which algorithms should be transitioned to operational support for USSF.

PHASE III DUAL USE APPLICATIONS: Phase III will be an operational hardened software package with these new SDA algorithms that will be transitioned to SpOC and SSC for space operations.

REFERENCES:

1. "Hao Peng and Xiaoli Bai, Imrpoving Orbit Prediction Accuracy through Supervised Machine Learning, Advances in Space Research (2018);

2. S. Fedeler, M. J. Holzinger, W. Whittacker, Tasking and Estimation for Minimum-Time Space Object Search and Recovery, Journal of the Astronautical Sciences, Vol. 69, pp. 1216-1249, July 2022;
3. S.N. Paul, B. Little, C. Frueh, Detection of Unknown Space Objects Based on Optimal Sensor Tasking and Hypothesis Surfaces Using Variational Equations, Journal of Astronautical Sciences, 10.1007/s40295-022-00333-z, July 2022;
4. Balducci, M., and B.A. Jones, "Probability of Collision Estimation and Optimization Under Uncertainty Utilizing Separated Representations", Journal of the Astronautical Sciences, Vol. 67, No. 4, pp. 1648-1677, 2020.";

KEYWORDS: space domain awareness; space domain awareness algorithms; data to decision; orbit determination; satellite tracking; satellite characterization