AIR FORCE
22.A SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) Phase I
PROPOSAL PREPARATION INSTRUCTIONS

Air Force (AF) Phase I proposal submission instructions are intended to clarify the Department of Defense (DoD) Broad Agency Announcement (BAA) as it applies to the topics solicited herein. **Firms must ensure proposals meet all requirements of the 22.A STTR BAA posted on the DoD SBIR/STTR Innovation Portal (DSIP) at the proposal submission deadline date/time.**

Complete proposals **must** be prepared and submitted via https://www.dodsbirsttr.mil/submissions/ (DSIP) on or before the date published in the DoD 22.A STTR BAA. Offerors are responsible for ensuring proposals comply with the requirements in the most current version of this instruction at the proposal submission deadline date/time.

Please ensure all e-mail addresses listed in the proposal are current and accurate. The AF is not responsible for ensuring notifications are received by firms changing mailing address/e-mail address/company points of contact after proposal submission without proper notification to the AF. **If changes occur to the company mail or email addresses or points of contact after proposal submission, the information must be provided to the AF SBIR/STTR One Help Desk.** The message shall include the subject line, "22.A 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.A STTR BAA.
- Air Force SBIR/STTR BAA Contracting Officers (CO):
    - Ms. Kristina Croake, kristina.croake@us.af.mil
    - Mr. James Helmick, james.helmick.2@us.af.mil

General information related to the AF Small Business Program can be found at the AF Small Business website, http://www.airforcesmallbiz.af.mil/. The site contains information related to contracting opportunities within the AF, as well as business information and upcoming outreach events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers (PTACs), http://www.aptacus.us.org. These centers provideGovernment contracting assistance and guidance to small businesses, generally at no cost.

CHART 1: Air Force 22.A STTR Phase I Topics Information at a Glance

Topic Number	Performance Period	Max STTR Funding	Technical Volume Contents
AF22A-T001	9 months	$150,000	White Paper NTE 10 Pages
AF22A-T002	9 months	$150,000	White Paper NTE 10 Pages
AF22A-T003	9 months	$150,000	White Paper NTE 10 Pages
AF22A-T004	9 months	$150,000	White Paper NTE 10 Pages
AF22A-T005	9 months	$150,000	White Paper NTE 25 Pages
AF22A-T006	9 months	$150,000	White Page NTE 25 Pages

PHASE I PROPOSAL SUBMISSION

DoD 22.A STTR BAA, 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. See Chart 1 (AF-1) for proposal dollar values, periods of performance, and technical volume content.

Limitations on Length of Proposal

The Phase I Technical Volume page limits identified in Chart 1 do not include the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j). 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.

Phase I Work Plan Outline

NOTE: The AF uses the Phase I Work Plan Outline in lieu of a Statement of Work (SOW). DO NOT include proprietary information in the Work Plan Outline. This will necessitate a request for revision and may delay contract award, if selected.

In the Work Plan section, start with a Work Plan Outline in the following format:

1) Scope: List the major requirements and specifications of the effort.
2) Task Outline: Provide a brief outline of the work to be accomplished over the span of the Phase I effort.
3) Milestone Schedule
4) Deliverables
    a. Kickoff meeting within 30 days of contract start
    b. Progress reports
    c. Technical review within 6 months
    d. Final report with SF 298

Cost Volume: Cost information should be provided by completing the Cost Volume in DSIP and including the Cost Volume Itemized Listing specified below. The Cost Volume detail must be adequate to enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a-i below) regarding funds use if an award is received. The DSIP Cost Volume and Itemized Cost Volume Information will not count against the specified page limit. The itemized listing may be submitted in Volume 5 under the "Other" dropdown option.

a. **Special Tooling/Test Equipment and Material**: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness to the work proposed. Special tooling and test equipment purchases must, in the opinion of the CO, be advantageous to the Government and relate directly to the effort. It may include such items as innovative instrumentation and/or automatic test equipment.

b. **Direct Cost Materials**: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, prices and where appropriate, purpose.

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

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

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

f. **Subcontracts**: Involvement of a research institution in the project is required. Involvement of other subcontractors or consultants may also be desired. Describe in detail the tasks to be performed in the Technical Volume and include information in the Cost Volume for the research institution and any other subcontractors/consultants. The proposing SBC must perform a minimum of 40% of the Phase I R/R&D and the research institution must perform a minimum of 30%. Work allocation is measured by direct and indirect costs AFTER REMOVAL OF THE SBC's PROPOSED PROFIT. This work allocation requirement is codified in statute; therefore, the Government CO cannot waive it. STTR efforts may include subcontracts with Federal Laboratories and Federally Funded Research and Development Centers (FFRDCs). NOTE: Not all Federal Laboratories or FFRDCs qualify as research institutions.

Support subcontract costs with copies of executed agreements. The supporting agreement documents must adequately describe the work to be performed. At a minimum, each planned subcontractor's information must include a SOW with a corresponding detailed cost proposal.

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 hourly or daily rate.

h. **DD Form 2345**: For proposals submitted under export-controlled topics, either by International Traffic in Arms or Export Administration Regulations (ITAR/EAR), a copy of a 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. The DD Form 2345 must be approved prior to award if proposal is selected for negotiations and funding.

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. Please contact one of the Contracting Officer identified on A-1 with any concerns.

i. **Cost Sharing**: Cost share is not accepted as part of Phase I proposals.

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

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

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

1) The Air Force Phase I proposal shall follow the topic-specific information in Chart 1.

2) It is mandatory complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, Company Commercialization Report, and Fraud, Waste and Abuse Certificate of Training Completion -- be executed electronically through DSIP.

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

AIR FORCE PROPOSAL EVALUATIONS
The AF will utilize the Phase I proposal evaluation criteria in the DoD 22.A STTR BAA with the factors in descending order of importance.

The AF will utilize Phase II evaluation criteria in the DoD 22.A STTR BAA with the factors in descending order of importance.

Proposal Status and Feedback

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Cover Sheet will be notified by e-mail regarding proposal selection or non-selection. Small businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced.

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

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

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

Refer to the DoD STTR 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 BAA Contracting Officers.

AIR FORCE SUBMISSION OF FINAL REPORTS

All final reports will be submitted to the awarding AF organization in accordance with the purchase order or contract. 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 TPOC's review using the DoD 22.A STTR BAA Phase I review criteria. All Phase I awardees will be provided an opportunity to submit a Phase II proposal unless the Phase I purchase order has been terminated for default or due to non-performance by the Phase I company.

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

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

AIR FORCE STTR 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 Air Force also reserves the right to change any administrative procedures at any time to improve management of the AF STTR Program.

AIR FORCE 22.A STTR Phase I Topic Index

AF22A-T001 TITLE: Active techniques for ground-based space domain awareness

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Sensors; Electronics; Battlespace

OBJECTIVE: The objective of this project is to develop and demonstrate key components that would help make sodium-beacon or Rayleigh-beacon adaptive optics practical for military, ground-to-space imaging applications. Current commercial laser systems used to produce sodium and Rayleigh beacons were developed for astronomical applications. These commercial lasers are not suited for smaller military telescopes, which are typically installed in locations with much worse turbulence, when compared to astronomical telescopes. The objective is to develop these laser components and demonstrate them on-sky, in conditions that are representative of typical sites for ground-based observations of earth-orbiting satellites. These components could be demonstrated on government, university, or civilian telescopes.

DESCRIPTION: AFRL supports the US Space Force in researching and developing effective, affordable techniques to identify, track, and characterize satellites in earth orbit. Radar, although it is expensive to build and operate, works for satellites in low-earth orbit. However, because of the distances involved, only a few specialized ground-based radars are capable of tracking satellites in geosynchronous orbit. Compared to ground-to-space radars, ground-based optical telescopes are less expensive to build and operate; in addition, they work well for satellites in all orbits. However, atmospheric turbulence limits the resolution and effectiveness of ground-based optical telescopes. Laser-beacon adaptive optics is an established technique to overcome the effects of atmospheric turbulence.

However, there remain significant challenges to improving the utility and effectiveness of laser beacon adaptive optics for military applications. There are two main types of laser beacons used in adaptive optics, Rayleigh beacons and sodium beacons. Rayleigh beacons are formed by scattering light from molecules of nitrogen and oxygen lower in the atmosphere; typical altitudes range from 10 km to 20 km. Pulsed lasers are typically used for Rayleigh beacons so that the light may be sampled from a particular altitude by using a technique called range gating. Because Rayleigh scattering is much stronger for shorter wavelengths of light, common wavelengths for Rayleigh beacons are 355 nm and 532 nm.

Because Rayleigh beacons rely on scattering from air molecules, they are limited to relatively low altitudes where the density of air molecules is higher. Light from the beacon traverses a cone of air above the telescope, with the beacon at the apex of the cone and the telescope pupil at the base of the cone. If a Rayleigh beacon is used for a larger telescope, the cylindrical column of air above the telescope will not be well sampled. Because of this cone effect, Rayleigh beacons are suitable only for smaller telescopes of up to 2 m in diameter. Sodium beacons are formed from scattering light from a layer of ionic sodium that is centered at an altitude of 90 km above the ground. Because of their high altitude, sodium beacons sample a much larger cone of air when compared to Rayleigh beacons. So, they are better suited for use with large telescopes.

Lasers for bright Rayleigh and sodium beacons are large and heavy; they are difficult to mount on typical military telescopes, which tend to be much smaller than astronomical telescopes. In addition, military telescopes are typically deployed to locations where the atmospheric turbulence is much worse than locations for astronomical observatories. To make matters worse, when a ground-based telescope tracks a satellite in low-earth orbit, it must slew quickly across the sky. This, in effect, creates a situation that is equivalent to a strong wind blowing across the aperture of the telescope. The combination of these two factors means a laser beacon for military purposes must be much brighter than a laser beacon for astronomy.

Another factor to consider is the risk that laser beacons pose to the safe operation of aircraft. Visible laser beacons are not eye-safe, thus considerable effort is necessary to avoid blinding aircraft pilots. Ultra-violet lasers are not transmitted by aircraft windscreens, but the silver mirror coatings typically used in telescopes do not reflect ultra-violet wavelengths well. Furthermore, the quantum efficiency of typical wave-front sensor cameras is low at ultra-violet wavelengths. Thus, AFRL is seeking development of key components that would help to make sodium-beacon or Rayleigh-beacon adaptive optics practical for military ground-to-space imaging applications. These components are listed below.
• On-telescope (side- or center-launched) Rayleigh beacon laser (ultra-violet and visible)
• Ultra-violet (eye-safe) laser beacon
• Uplink compensation of laser beacon to reduce beacon size
• Polychromatic laser beacon for sensing tilt and high-order aberrations
• Laser-beacon (Rayleigh and sodium) simulator for laboratory bench-top testing
• Hybrid Rayleigh-sodium beacon adaptive optics
• Tilt anisoplanatism compensation
• Electronic camera shutter or low-radio-frequency-interference Pockels cell for gating Rayleigh beacon return • Using adaptive optics telemetry in near-real-time for improving laser-beacon imaging and detection of closely spaced objects
• Advanced wave-front sensors and cameras for laser beacon adaptive optics

PHASE I: Phase I deliverables include a report that describes thoroughly concepts, analyses, and simulations for laser beacon components that are suitable for military ground-to-space imaging applications. These analyses and simulations must show that the proposed components are effective and affordable. The report should describe the components at a level suitable for a conceptual design review. (See the references section for the contents of a conceptual design review.) The report shall include a plan for demonstrating the laser components on-sky, in conditions that are representative of typical sites for ground-based observations of earth-orbiting satellites.

PHASE II: Phase II deliverables include a detailed design of laser beacon components suitable for military ground-to-space imaging applications. This design must illustrate the proposed components are effective and affordable. The design documents should describe the components at a level suitable for preliminary and critical design reviews. (See the references section for the contents of preliminary and critical design reviews.)

The report shall include a detailed plan for demonstrating the laser components on-sky, in conditions representative of typical sites for ground-based observations of earth-orbiting satellites. As cost and schedule constraints allow, a prototype component shall be built, tested, and demonstrated on-sky at government, university, or civilian observatory.

PHASE III DUAL USE APPLICATIONS: A Phase III effort would require identifying a suitable transition partner, which could be a government program office, a government contractor or other commercial entity, or a civilian astronomical observatory.

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

REFERENCES:

1. Laser beacons or laser guide stars https://en.wikipedia.org/wiki/Laser_guide_star;
2. Conceptual Design Review https://en.wikipedia.org/wiki/Engineering_design_processConcept_Generation

KEYWORDS: laser beacon; laser guide star; Rayleigh beacon; polychromatic beacon; adaptive optics; tilt anisoplanatism; wave-front sensor; electronic shutter

TPOC: Robert Johnson,
Phone: (505) 379-1743
Email: robert.johnson.104@spaceforce.mil

AF22A-T002 TITLE: Additive Manufacturing Techniques for Astronomical Mirror

TECH FOCUS AREAS: Directed Energy

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: This topic's outcome will be ability to create a telescope mirror not requiring much/any figuring to be usable for observing space objects.

DESCRIPTION: Efforts will aim to develop techniques/technologies to allow 3D printing at nanometer scales to produce parabolic/spherical mirrors requiring little to no figuring or modification. Visible light is in the range of 400 - 700 nm and typical figuring of astronomical telescopes is to the wavelength/10 or better.

Achieving this level of figuring with a 3D printer will require either the ability to print at the nanometer scale, or some technique to get the nanometer figure at a larger print scale. The Air Force is looking for a solution eventually providing the ability to mass produce custom size/shape mirrors for use in telescopes supporting Space Domain Awareness at reduced costs and at lighter weights to improve performance.

PHASE I: Investigate the capabilities of various Additive Manufacturing devices and techniques for micrometer-to-nanometer-scale accuracies. Research how those capabilities could be improved to provide required accuracy to 3D print a quality mirror. Research various printing materials providing the strength required for a size-able mirror to retain its shape when used in a telescope. Investigate techniques to make the process scalable; being able to 3D print a meter-class mirror for a telescope could provide additional opportunities for successful technology transition.

PHASE II: The contractor will demonstrate the ability to 3D print a high-quality mirror that can be used for astronomical purposes by printing an 8-inch mirror with an approximate focal length of 840mm (F/4 focal ratio) and a surface figure of wavelength/10 (./10). The mirror will be assembled into a Newtonian telescope design to demonstrate its ability to hold its shape in actual use. The contractor will, in the course of this phase also demonstrate the tradeoffs of time to print vs. the quality of the printed mirror (./4 vs. ./10 figuring). The contractor should make contact with telescope manufacturers during this phase to garner interest in their technique/potential products. The resulting telescope will be provided to the Space Force for evaluation under normal operations.

PHASE III DUAL USE APPLICATIONS: The contractor will demonstrate the scalability of the technology/techniques to a twenty-inch mirror with wavelength/10 figure.
For dual use potential: Recently there has been a shortage of commercial, hobbyist telescopes due to supply issues from non-indigenous manufacturers. This capability could relieve this shortage.

REFERENCES:

1. https://3dprint.com/238521/nanofabrica-micron-resolution-3d-printing-platform/
2. https://www.energy.gov/science/bes/articles/how-3d-print-nanoscale
3. https://onlinelibrary.wiley.com/doi/abs/10.1002/adma.202001675?af=R

4. https://www.researchgate.net/publication/341454859_3D_Printing_of_Micrometer-Sized_Transparent_Ceramics_with_On-Demand_Optical-Gain_Properties

KEYWORDS: Additive Manufacturing; Telescope Mirrors; 3D Printing; Astronomical Mirrors; Nanometer scale

TPOC: Waid Schlaegel
Phone: (505) 853-3402
Email: waid.schlaegel@us.af.mil

AF22A-T003 TITLE: Distributed Satellite Autonomy and Multi-perspective Data Fusion

TECH FOCUS AREAS: Autonomy

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Research and develop algorithms applied distributed satellite autonomy for clustered satellite systems as well as leveraging multi-perspective observations and measurements.

DESCRIPTION: Academic circles have investigated the topic of distributed collaborative control and autonomy for decades and recent applications to UAV's, warehouse servicers, ground robotics and more are increasingly available. More specifically, the topic of distributed collaborative autonomy applies to the situation where a group of agents share their information to achieve a common task.

However, there exist numerous challenges of applying this work to the space domain that may not be seen in terrestrial domains, in particular, communication networks between satellites and/or ground stations are dynamic and are, in general, low bandwidth and throughput, contain significant latencies. Limited computational hardware requires lightweight algorithms to compute correct collaboration tasks, manage scalability and fuse agents' sensor measurements.

Moreover, space is growing increasingly congested and contested, for which the resiliency of the space domain must be assured. The objective of this STTR is to address the resiliency of the space domain through autonomous mission distribution of satellite systems. More specifically, the Offeror will research, develop and test lightweight distributed satellite autonomy of heterogeneous sensors and consider the impact of multi-perspective sensor fusion into the autonomous architecture. The capabilities of this software and algorithm-based approach will enhance the future of the space domain architecture. Offerors are encouraged to work with prime contractors to facilitate technology transition. Offerors should clearly indicate in their proposals what Government furnished property or information are required to conduct this effort.

PHASE I: Conduct a comprehensive comparative assessment and trade-off study of distributed autonomy architectures, algorithms and techniques that are computationally efficient and with low communication throughput requirements.

PHASE II: Design, implement, integrate and test the most promising and effective instantiation of the distributed autonomy algorithms in an AFRL/RV Laboratory Environment. Conduct analysis and simulations to demonstrate the effectiveness and resilience of the algorithms. Assess the implementation overhead of the candidate techniques and conduct through trade-off studies.

PHASE III DUAL USE APPLICATIONS: Develop flight ready software for implementation into future AFRL or other Government flight missions and laboratory experiments.

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

REFERENCES:
1. C. Araguz, E. Bou-Balust, E. Alarcon, “Applying autonomy to distrusted satellite systems: Trends, challenges and future prospects,” Systems Engineering, 21:5, 401-416, Sept. 2018 ;
2. D. Selva, A. Golkar, O. Korobova, I. L. i Cruz, P. Collopy, and O. L. de Weck, “Distributed Earth Satellite Systems: What Is Needed to Move Forward?” Journal of Aerospace Information Systems 14:8, 412-438 2017;
3. S. A. Szklany, J. L. Crassidis and S.S. Blackman, "Centralized and Decentralized Space Object Estimation and Data Association with Pattern Recognition", John L. Junkins Symposium, College Station, TX, May 2018.

KEYWORDS: Distributed Satellite Autonomy; Autonomy; Sensor-Fusion

TPOC: Sean Phillips
Phone: (505) 853-8531
Email: sean.phillips.9@us.af.mil

AF22A-T004 TITLE: Satellite Fault Identification

TECH FOCUS AREAS: General Warfighting Requirements (GWR)

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Currently, for USSF satellites there is a team of >5 SMEs furiously monitoring the state of a satellite's health. Fault classification software plus already existing fault detection software would remove the need for constant monitoring. This would not only allow the operators to focus on the congested and contested manner of space but also mitigate faults in a satellite quickly and effectively.

DESCRIPTION: For an operator to mitigate a satellite fault quickly and effectively, the fault's cause must be understood. This requirement is due to the fact many faults have similar effects on the satellite but completely different causes. For instance, a solar Coronal Mass Ejection (CME) looks similar to a developer's bug in the software and various types of cyber-attacks. All of these faults might require completely different mitigation steps. For a CME, one way to fix the satellite is a restart after the event, the developer's code fix should be uploaded, and the cyber-attack could require a variety of responses depending on the attacker and the severity of the attack. These events also might not exist in the same dataset if they exist at all [1,2]. Therefore, this classification must also work for unknown unknown events so that it can be prepared to interact with the dynamic environment of space.

This topic's objective is to develop algorithms and code classifying a detected fault. The contractor will be given different satellite datasets either simulated or real on which to train. A separate dataset will be provided to prove out the algorithm.

PHASE I: In Phase I, selected companies will conduct a comprehensive comparative assessment with trade-offs of various classification algorithms and approaches. Implementation complexity of candidate techniques and conduct trade-offs will be assessed with respect to impact on SWAP-C and operational suitability. Deliverables of this should include a trade study and appropriate analysis reporting.

PHASE II: If selected for Phase II, companies will design, implement, integrate, and test the most promising and effective algorithm with ground software to classify detected satellite faults in near real time. Deliverables will include any relevant reporting analysis and software developed where appropriate.

PHASE III DUAL USE APPLICATIONS: In cooperative efforts with one or more satellite software manufacturers and military satellite system developers, Phase III efforts would integrate the proposed algorithms with satellite software; demonstrate the algorithm running on board a satellite; and evaluate transition opportunities for utilization in approved Government civilian 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. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the proposed tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the Air Force SBIR/STTR Help Desk: usaf.team@afsbirsttr.us

REFERENCES:
1. Trevor Hastie, Robert Tibshirani, and Jerome Friedman. The Elements of Statistical Learning.Springer, New York, NY, 2001.;
2. D. T. Magill. Optimal adaptive estimation of sampled stochastic processes. IEEE Transactions on Systems, Man and Cybernetics, AC-10:434–439, October 1965.

KEYWORDS: Satellite Faults; fault classification

TPOC: Michelle Simon
Phone: 907-250-0830
Email: michelle.simon.1@us.af.mil

AF22A-T005 TITLE: Characterization of Store Trajectory Dynamics Released from Internal Cavities Using Machine Learning, Artificial Intelligence and Other Advanced Data Analysis Techniques

TECH FOCUS AREAS: Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Information Systems; Air Platform

OBJECTIVE: This topic's objective is to develop analysis techniques via application of machine learning, artificial intelligence and/or other advanced data analysis techniques to evaluate and characterize large amounts of trajectory data generated for stores released from an internal cavity weapons bay. The goal would be to utilize such techniques to identify and subsequently exploit potential linkages between flow conditions in the cavity at and after the time of release with the disparity of the store trajectories observed due to variation in release time.

DESCRIPTION: A large dataset consisting of approximately 100 cases is currently being generated via high-fidelity CFD simulating the trajectories of small, light-weight stores being released from internal weapons bays (cavities) at high speeds. The simulation in this dataset primarily consists of the store configuration being held in carriage for some period of time and then released using a prescribed ejector profile, with the release time being the only variation in the simulations. It has been shown that the time of release of the store has a significant impact on its subsequent trajectory due to the unsteady flow-field in the cavity. The existing CFD dataset consists of high-frequency integrated force/moment components acting on the store, two-dimensional flow-field representations at various spanwise locations and heights in the cavity, and pressure time histories at various positions on the cavity walls/ceiling and the store prior to release as well as during the trajectory.

Additional data could also be collected during subsequent simulations as needed to develop appropriate analysis techniques. This rich data set will be provided as a training set in order to use various AI/ML or other analysis techniques to attempt to determine if there is some predictable cavity flow-field and/or force/moment state either 1) at the time of release and/or 2) after release while the store is traversing the cavity, shear layer and/or free-stream that leads to specific trajectory states. Of particular interest are the states associated with “bad” releases, defined as the distance between the store center of gravity and aircraft hardware not monotonically increasing or the store entering the free stream with high rates of pitch and/or yaw.

PHASE I: Phase I efforts will determine the scientific and technical merit and feasibility of application of AI, ML and/or advanced analysis techniques to determine root causes for a specified store to reach a particular state when released from an internal store configuration. High-fidelity, unsteady CFD of 6DOF trajectories generated for a particular store released at various times will be provided as GFE.

Tangible outcomes for the Phase I effort would be the demonstration of a practical process to relate particular states of the cavity to specific trajectory behaviors. The envisioned main deliverable for Phase I would be a report documenting the process with sufficient detail to allow evaluation by the government and example(s) of its application on the dataset provided. Identification of the overall plan to mature the concepts into a useable tool along with plans to generate additional data needed to support development/expansion of method to additional configurations should also be reported.

PHASE II: Further develop the approach to demonstrate its ability to identify conditions in the cavity (including the shear layer) related to trajectories. This identification should be probabilistic in nature, where certain flow features and/or force/moment states produce, bad trajectories are observed to exist in some statistically significant number of cases.

Extension of approach to data from other stores and/or other cavity configurations would be encouraged. Tangible outcomes and expected deliverables for the Phase II effort would include stand-alone software that would take in high-fidelity unsteady CFD data and produce output that could identify release points or flow states/flow-field features associated with problematic trajectories. A stretch goal would be the inclusion of surrogate modeling of key cavity environmental features that would permit reduced order evaluation of configurations beyond the training data set.

PHASE III DUAL USE APPLICATIONS: Phase III efforts will focus on transitioning the developed technology to a working commercial or warfighter software/processes. Solutions developed will be immediately relevant to precision airdrop, cargo and weapons release, among a whole range of commercial and military applications. If a viable approach to identify conditions associated with bad trajectories are identified, this would allow potential flow-control solutions to be investigated to "fix" these conditions and diminish problematic releases. They would be in a position to supply future software/processes to the Air Force, and other DoD components to facilitate future weapons bay designs that would improve separation characteristics.

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

REFERENCES:
1. Brunton, S. L., Noack, B. and Koumoutsakos, P., "Machine Learning for Fluid Mechanics", Annual Review of Fluid Mechanics, Vol. 52, pp 477-508, 2020 (doi:10.1146/annurev-fluid-010719-060214);
2. Sun et al., "Resolvent Analysis of Compressible Laminar and Turbulent Cavity Flow", AIAA Journal, Vol .58, No. 3, pp. 1046-1055,(doi:10.251.4/J058663)

KEYWORDS: Artifical Intelligence; Machine Learning; Store Separation; Cavity; Computational Fluid Dynamics; Six-Degree-of-Freedom Trajectories

TPOC: Scott Sherer
Phone: 937-713-7062
Email: scott.sherer@us.af.mil

AF22A-T006 TITLE: Development of Integrated Infrared Focal Plane Arrays on Si, Requiring No Hybridization

TECH FOCUS AREAS: Microelectronics

TECHNOLOGY AREAS: Sensors

OBJECTIVE: This topic seeks to develop infrared focal plane arrays (FPAs) directly onto silicon readout integrated circuitry without hybridization, operating at 2 um or longer, and using GeSn or GeSiSn absorbing layers.

DESCRIPTION: Conventional short- and mid-wave infrared (SWIR and MWIR) detectors based on III-V (i.e., GaInSb) or II-VI (i.e., HgCdTe) materials are relatively expensive and incompatible with silicon-based readout integrated circuitry (ROIC), requiring hybridization (typically in bump bonding) which is very expensive. Technologies based on Si and SiGe are pervasive for electronic applications, but indirect energy gaps prevent their use as the active elements in optoelectronic devices. Recent progress in the material system of Group-IV alloys containing Sn (GeSiSn and GeSn) and the potential of a direct energy gap for certain compositions promises significant optical performance which is compatible with and will allow for direct integration with Si complementary metal-oxide-semiconductor (CMOS) device processing. Extremely high-quality thin films and initial proof-of-concept emitters and detectors have been demonstrated on Ge substrates but corresponding films on Si substrates suffer from high defect levels due to the lattice mismatch of high Sn content GeSiSn and GeSn alloys necessary for direct energy gap devices. The use of one or more buffer layers (e.g., a Ge virtual substrate alone or with GeSn overlayers) on Si have been used to reduce such defects but impede device integration. Therefore, development of easily integrated emitters and detectors on Si substrates are critical for mass production of optoelectronic devices using standard CMOS production equipment and large diameter Si wafers. A number of patterned deposition techniques have been developed for other heteroepitaxy systems (e.g. GaN on SiC or Al_2O_3 substrates), including nanopillars, template growth, epitaxial overgrowth, and planarization to reduce structural defects such as dislocations. Therefore, it should be feasible to use similar approaches or develop novel ones to synthesize high quality GeSiSn or GeSn films directly on Si ROICs without the need for hybridization. Such layers could be used to fabricate integrated FPAs operating in the SWIR or MWIR spectral regions. Thus, if successful, this technology could be rapidly scaled and industrialized to produce low cost, large format imagers.

PHASE I: Demonstrate the feasibility of novel techniques for growth of GeSiSn and/or GeSn films directly on Si substrates. Design device structures incorporating barriers for dark current reduction, including single and complementary barrier architectures that minimize optical and electrical crosstalk between devices. All devices should be vertical to facilitate mating to either a commercially available readout integrated circuit (ROIC) or a fanout for testing purposes. Provide experimental evidence for improved material performance of device quality epitaxial films grown on Si substrates, improved infrared absorption, and narrower X-ray rocking curves compared to typical films synthesized on traditional vacuum deposited buffer layers. Deliver a GeSiSn or GeSn film on 2" silicon wafer or larger with a minimum of 500 nm thickness for material characterization, as well as a processed variable area device die for photodetector testing.

PHASE II: Companies selected for Phase II will fabricate and characterize integrated focal plane array (FPA) detectors operating within the spectral range of 2 - 5 um on Si readout intectrated circuits (ROICs). The external quantum efficiency (EQE) of the devices should be greater than 20% from 1.1 to more than 2.0 um and the dark current density should be less than 1 uA per sq. cm at temperatures of 200 K or greater. Deliver a silicon fanout (minimum 32 x 32, <50 um pitch) using direct deposition to verify dark current density and EQE. Deliver full FPAs for array level testing.

PHASE III DUAL USE APPLICATIONS: In Phase III, the device quality GeSiSn and/or GeSn films will be used to make infrared device structures as required by military and commercial customers including those who manufacture integrated circuits and IR optical detectors.

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

REFERENCES:
1. C.-H. Tsai, K.-C. Lin, C.-Y. Cheng, K.-C. Lee, H. H. Cheng, G.-E. Chang, “GeSn lateral p-i-n waveguide photodetectors for mid-infrared integrated photonics”, Opt. Lett. 46, 864 (2021);
2. H. Kumar and R. Basu, “Effects of Defects on the Performance of Si-Based GeSn/Ge Mid-Infrared Phototransistors”, IEEE Sensors J. 21, 5975 (2021);
3. H. Tran, T. Pham, J. Margetis, Y. Zhou, W. Dou, P. C. Grant, J. M. Grant, S. Al-Kabi, G. Sun, R. A. Soref, J. Tolle, Y.-H. Zhang, W. Du, B. Li, M. Mortazavi, S.-Q. Yu, “Si-Based GeSn Photodetectors toward Mid-Infrared Imaging Applications”, ACS Photonics 6, 2807 (2019);
4. C. Chang, H. Li, C.-T. Ku, S.-G. Yang, H. H. Cheng, J. Hendrickson, R. A. Soref, G. Sun, “Ge0.975Sn0.025 320 x 256 imager chip for 1.6-1.9 um infrared vision, Appl. Opt. 55, 10170 (2016);
5. Matthew Coppinger, John Hart, Nupur Bhargava, Sangcheol Kim, and James Kolodzey, “Photoconductivity of germanium tin alloys grown by molecular beam epitaxy”, Appl. Phys. Lett. 102, 141101 (2013);
6. R. Roucka, J. Mathews, C. Weng, R. Beeler, J. Tolle, J. Menendez, and J. Kouvetakis, “High-performance near-IR photodiodes: a novel chemistry-based approach to Ge and Ge–Sn devices integrated on silicon,” IEEE J. Quantum Electronics 47, 213 (2011);
7. J. Taraci, S. Zollner, M. R. McCartney, J. Menendez, M. A. Santana-Aranda, D. J. Smith, A. Haaland, A.V. Tutukin, G. Gundersen, G. Wolf, and J. Kouvetakis, “Synthesis of silicon-based infrared semiconductors in the Ge-Sn system using molecular chemistry methods,” J. Am. Chem. Soc. 123, 10980 (2001)

KEYWORDS: GeSiSn; GeSn; silicon; germanium; silicon-germanium-tin; Buffer layers; Molecular Beam Epitaxy; MBE; CVD; chemical vapor deposition; epitaxial lateral overgrowth (ELO); detectors; Group IV photonics; silicon photonics; optoelectronic devices; device fabrication; growth;

heterostructures; radiative recombination; quantum efficiency; semiconductor characterization; infrared; focal plane arrays (FPA)

TPOC: Bruce Claflin
Phone: (937) 713-8740
Email: bruce.claflin.1@us.af.mil